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SERVICE D'ECONOMIE DE LA SANTE ET DES PRODUCTIONS ANIMALES

Contribution à l'évaluation du programme de contrôle de l'échinococcose kystique au Maroc

Contribution to the evaluation of the control program of cystic echinococcosis in Morocco

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Epigraphe

كُن اِبنَ مَن شِئتَ واِكتَسِب أَدَباً يُغنيكَ مَحمُودُهُ عَنِ النَسَبِ

فَلَيسَ يُغني الحَسيبُ نِسبَتَهُ بِلا لِسانٍ لَهُ وَلا أَدَبِ

إِنَّ الفَتى مَن يُقولُ ها أَنا ذا لَيسَ الفَتى مَن يُقولُ كانَ أَبي

علي بن أبي طالب

“Ali ibn Abi Talib ”

Traduction

Soyez le fils de qui vous souhaitez et acquérez l'honneur

Et épargnez-vous aux louanges liées à votre lien de parenté

Ainsi une personne ne s'enrichit-il pas par son nom de famille

Mais par ses paroles et sa politesse

Le vrai homme est celui qui dit voilà qui je suis

Pas celui qui dit qui était son père

Composition du jury

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Abréviation

ANOFEL : Association Française des Enseignants de Parasitologie et Mycologie

BMH : Bureau Municipal d'Hygiène

CE : Cystic echinococcosis

CIWF: Compassion In World Farming

DALY: Disability Adjusted Life Year

DELM : Direction de l'Epidémiologie et de Lutte contre les Maladies

FGD : Focus groupe de discussion

HCP : Le Haut-Commissariat au Plan

HD : Hôte Définitif

HI : Hôte Intermédiaire

IDII: In-Depth Individual Interview

NHCP: National hydatidosis control program

OIE : Organisation mondiale de la santé animale

OMS : Organisation Mondiale de la Santé

ONSSA : Office National de Sécurité Sanitaire des produits Alimentaires

PNLH : Programme national de lutte contre l'hydatidose

PP : Partie Prenante

USD : Dollar américain

WHO : World Health Organization

zDALY: Disability Adjusted Life Year for zoonotic diseases

Résumé

L’hydatidose ou échinococcose cystique est une zoonose majeure et pourtant négligée. Elle est endémique dans plusieurs pays à travers le monde, dont particulièrement le pourtour méditerranéen. Au Maroc, malgré les efforts menés dans le cadre d’un programme national de lutte contre l’hydatidose (PNLH), initié depuis 2007, cette zoonose présente toujours une cause de morbidité importante. Face à cette situation, l'établissement d'une proposition efficace pour améliorer le PNLH est nécessaire. Notre étude part du principe que, pour améliorer le PNLH, il faut d’abord l’analyser et comprendre ses différents enjeux et facettes. Une approche multidisciplinaire a été suivie, basée sur l’estimation des pertes monétaires et non monétaires causées par cette zoonose, ainsi que des analyses participatives de ses parties prenantes, de sa mise en œuvre et des voies de son amélioration. Nous avons pu relever les multiples défis auxquels fait face le PNLH et avons étudié la possibilité d’instaurer une nouvelle stratégie de lutte, basée sur la vaccination des ovins et le traitement des chiens. Théoriquement apte à éliminer cette zoonose au bout de 15 ans, le succès de cette stratégie dépendra en effet de l’aptitude du programme national à la mener et de son acceptabilité auprès de la population directement concernée.

Une évaluation précise de la charge de morbidité est essentielle pour la sensibilisation des décideurs, car elle permet de donner la priorité au financement des mesures de lutte en temps opportun. Dans ce but, une première étude a été menée pour estimer les pertes économiques causées par cette zoonose à l'échelle nationale et provinciale en combinant des méthodes financières et non financières. Au niveau de la santé humaine, les pertes d’années de vie corrigées de l’incapacité (DALY), les frais médicaux et les pertes de productivité ont été estimés. Chez l’animal, les pertes liées aux saisies d'organes au niveau des abattoirs et les pertes de production causées par une réduction du lait, de la fertilité, du poids de la carcasse et de la production de laine ont été estimées aussi. L’indicateur zDALY, modifiant l’indicateur DALY pour y intégrer les impacts de santé animale des maladies zoonotiques, a été calculé afin de joindre ces deux composantes. Des simulations de Monte-Carlo ont été utilisées pour calculer les valeurs numériques approchées. Les pertes totales oscillent entre 222 millions USD et 234 millions USD. Les DALYs ont été estimés au niveau national à 0,5 an pour 100 000 habitants et le zDALY à 55 ans pour 100 000 habitants. Selon ces évaluations, les pertes perçues ne représentent que la pointe de l'iceberg, la majeure partie

des pertes étant causée par la perte de la productivité humaine chez les cas non diagnostiqués et les pertes de production animale. Cette étude a mis en lumière les pertes énormes causées par cette zoonose, sur tout le territoire marocain, indiquant la nécessité d'une amélioration des mesures de prévention et de contrôle.

Les résultats de la première étude ont montré la persistance de l'hydatidose/échinococcose au Maroc et la non-atteinte des objectifs du PNHL. Ceci nous a poussé à poser la question des causes de cet échec. Pour répondre à cette question, une deuxième étude sur les enjeux et les obstacles qui ont entravé la réussite du PNHL a été menée. Une approche qualitative a été menée au niveau de cinq régions du Maroc : Rabat-Salé-Kénitra; Béni Mellal-Khénifra; Sous-Masaa; Laâyoune-Sakia El Hamra et Guelmim-Oued Noun. Nous avons posé le choix pour cette étude d'ouvrir le cadre d'application au-delà de la seule hydatidose/échinococcose, nommément à la rage et à la tuberculose bovine, afin de mettre en évidence les défis communs que le contrôle de ces zoonoses présente. Des observations participantes et 81 entretiens individuels ont été réalisés avec les vétérinaires, les autorités locales et les abatteurs. Les enregistrements ont fait l'objet d'une transcription intégrale et les narratifs été analysés avec le logiciel R, en utilisant le package RQDA. L'étude a révélé un manque de rigueur professionnelle, un manque de cadre législatif, ainsi qu'un chevauchement de pouvoirs et d'intérêts entre les différentes structures, alors que la stratégie multisectorielle est essentielle dans la lutte contre les zoonoses. Cette analyse a amené à notre troisième étude, qui a analysé les parties prenantes du PNLH pour approfondir notre compréhension des relations de chaque acteur avec le programme.

La troisième étude vise donc à analyser les acteurs du PNLH pour identifier des pistes de son amélioration et de proposer des voies plus adaptées. Des parties prenantes ont été identifiées, et au total, 163 entretiens semi-structurés ont été menés dans les mêmes régions que la deuxième étude, ainsi qu'un atelier interministériel à Rabat. Les catégories classiques d'analyse des parties prenantes, c'est-à-dire l'implication, l'intérêt, l'importance, l'influence, la priorité et le pouvoir, ont été semi-quantifiées. Un cadre analytique a été proposé combinant ces catégories pour évaluer les acteurs par trois attributs: l'appropriation des mesures, l'agence politique et l'agence sociotechnique. L'étude a mis en évidence une organisation déficiente de la diversité des acteurs impliqués, se traduisant dans une déficience dans les trois attributs mobilisés. Cette étude a proposé

une approche analytique et informative, particulièrement utile pour une orientation de la lutte contre les zoonoses dans laquelle la coordination multisectorielle est capitale.

Dans la recherche de nouvelles stratégies de lutte contre l'hydatidose/échinococcose, des essais de vaccination des ovins (le vaccin EG95) associés au traitement anthelminthique des chiens ont été menés dans le Moyen Atlas, la région du pays ayant la prévalence la plus élevée. Cette étude présente l'analyse de la faisabilité et de l'acceptabilité sociale de cette stratégie, dont le but est de tracer une approche pour l'élaboration d'un guide pour mener une telle intervention dans l'avenir. Onze groupes de discussion et seize entretiens individuels approfondis ont été menés avec les éleveurs, les femmes, les autorités locales, les médecins et vétérinaires privés, ainsi que les fonctionnaires des structures responsables de la mise en œuvre potentielle du PNLH en parallèle avec les essais du vaccin. Les enregistrements ont été transcrits et analysés avec le logiciel R, en utilisant le progiciel RQDA. Cette étude a mis en évidence différentes réserves émises par les acteurs sur la faisabilité de la stratégie. L'étude a permis de collecter les propositions des participants pour une meilleure mise en place de cette nouvelle stratégie. Ces réserves et propositions devront impérativement être prises en compte pour l'élaboration d'un plan renouvelé.

En conclusion, l'étude a mis en évidence l'impact de l'hydatidose/échinococcose dans tout le territoire marocain, qui cause des pertes qui arrivent à 0.07% du PIB du Maroc. Ainsi, l'approche qualitative nous a permis d'abord de comprendre le fonctionnement du PNLH sur le terrain, et de proposer un schéma d'instauration d'une nouvelle stratégie de lutte, que théoriquement, pourra contrôler cette zoonose au bout de 15 ans.

Abstract

Cystic echinococcosis (CE) is a major zoonosis, however, it is neglected. It is endemic in several countries around the world, particularly around the Mediterranean. In Morocco, despite the efforts carried out within the framework of a national hydatidosis control program (NHCP), initiated in 2007, this zoonosis still presents a major cause of morbidity. Faced with this situation, the establishment of an effective proposal to improve the NHCP is necessary. Our study is based on the principle that, in order to improve the NHCP, we must first analyze and understand its different issues and facets. A multidisciplinary approach was followed, based on the estimation of monetary and non-monetary losses caused by this zoonosis, as well as participatory analyzes of its stakeholders, its implementation and ways of improving it. We were able to raise the multiple challenges facing the NHCP and studied the possibility of establishing a new control strategy, based on the vaccination of sheep and the treatment of dogs. Theoretically capable of eliminating this zoonosis in 15 years, the success of this strategy will indeed depend on the ability of the national program to carry it out and on its acceptability among the population directly concerned.

Accurate assessment of the burden disease is essential for sensitizing decision-makers, as it helps prioritize funding for timely control measures. In this objective, a first study was carried out to estimate the economic losses caused by this zoonosis at the national and provincial level by combining financial and non-financial methods. In terms of human health, loss of disability-adjusted life years (DALY), medical costs and productivity losses were estimated. For animals, organ seizure losses at slaughterhouses and production losses caused by reducing milk, fertility, carcass weight and wool production were also estimated. The zDALY indicator, modifying the DALY indicator to include the animal health impacts of zoonotic diseases, was calculated to combine these two components. Monte-Carlo simulations were used to calculate the approximate numerical values. Total losses range from USD 222 million to USD 234 million. DALYs were estimated nationally at 0.5 years per 100,000 person and zDALY at 55 years per 100,000 person. According to these assessments, perceived losses are only the tip of the iceberg, with most of the losses being caused by loss of human productivity in undiagnosed cases and losses in animal production. This study highlighted the enormous losses caused by this zoonosis, throughout Morocco, indicating the need for improved prevention and control measures.

The results of the first study showed the persistence of CE in Morocco and the failure that meet NHCP objectives. This prompted us to ask the question of the causes of this failure. To answer this question, a second study on the issues and obstacles that hindered the success of the NHCP was conducted. A qualitative approach was carried out in five regions of Morocco: Rabat-Salé-Kénitra; Béni Mellal-Khénifra; Sous-Masaa; Laâyoune-Sakia El Hamra and Guelmim-Oued Noun. We made the choice for this study to open the framework for application beyond hydatidosis alone, namely rabies and bovine tuberculosis, in order to highlight the common challenges that the control of these zoonoses presents. Participatory observations and 81 individual interviews were conducted with veterinarians, local authorities and slaughterers. The recordings were fully transcribed and the narratives analyzed with R software, using the RQDA package. The study revealed a lack of professional rigor, a lack of legislative framework, as well as an overlap of powers and interests between the different structures, while the multisectoral strategy is essential in the fight against zoonoses. This analysis led to our third study, which analyzed NHCP stakeholders to deepen our understanding of each stakeholder relationship with the program.

The third study, therefore aims to analyze the actors of the NHCP in order to identify avenues for improvement and to propose more suitable ways. Stakeholders were identified, and a total of 163 semi-structured interviews were conducted in the same regions as the second study, as well as an inter-ministerial workshop in Rabat. The classic categories of stakeholder analysis, i.e. involvement, interest, importance, influence, priority and power, have been semi-quantified. An analytical framework was proposed combining these categories to evaluate the actors by three attributes: the appropriation of the measures, the political agency and the socio-technical agency. The study highlighted a deficient organization of the diversity of the actors involved, resulting in a deficiency in the three attributes mobilized. This study proposed an analytical and informative approach, particularly useful for an orientation of the fight against zoonoses in which multisectoral coordination is essential.

In the search for new CE control strategies, sheep vaccination trials (EG95 vaccine) associated with anthelmintic treatment of dogs were carried out in the Middle Atlas, the region of the country with the highest prevalence. This study presents the analysis of the feasibility and social acceptability of this strategy, the aim of which is to outline an approach for the development of a guide for carrying out such an intervention in the future. Eleven focus groups and sixteen in-depth

individual interviews were conducted with breeders, women, local authorities, private doctors and veterinarians, as well as officials from the structures responsible for the potential implementation of the NHCP in parallel with the trials of the vaccine. Recordings were transcribed and analyzed with R software, using RQDA software package. This study highlighted various reservations expressed by the players on the feasibility of the strategy. The study made it possible to collect participants' proposals for a better implementation of this new strategy. These reservations and proposals must imperatively be taken into account for the development of a renewed plan.

In conclusion, the study highlighted the impact of CE throughout the Moroccan territory, which causes losses reaching 0.07% of Morocco's GDP. Thus, the qualitative approach allowed us first to understand the functioning of the NHCP in the field, and to propose a scheme for the establishment of a new control strategy, which theoretically, could control this zoonosis in 15 years.

Introduction

Depuis que l'élevage existe, les maladies animales représentent une menace pour les espèces animales, les communautés qui le pratiquent et les sociétés humaines dans leur ensemble. Ces maladies animales représentent une menace particulièrement grave pour le bien-être des populations et les économies régionales, et peuvent dans certains cas prendre une dimension planétaire. Elles constituent un frein important au développement social et économique des pays atteints et, dans le cas des zoonoses, posent un sérieux problème de santé publique. Parmi les zoonoses à répartition mondiale, on cite l'hydatidose/échinococcose cystique, le sujet de cette recherche.

Également appelée échinococcose hydatique, uniloculaire ou cystique, l'hydatidose est une zoonose majeure et néanmoins négligée. Elle est cosmopolite, affectant principalement les pays en développement et les zones rurales. Au Maroc, l'hydatidose sévit à l'état endémique. Selon le ministère de la santé du Maroc, entre 2009 à 2014, le nombre cumulatif de cas opérés à cause de kystes hydatiques était de 2114 personnes, soit une moyenne de 1.3 cas pour 100 000 habitants par an. Au niveau des abattoirs, d'après les registres des abattoirs, la prévalence de l'hydatidose/échinococcose en 2014 était de 12.9% chez les bovins, 9.33% chez camelins, 8.45 chez les ovins et 4.7% chez caprins. Pour faire face à cette zoonose, le Maroc a instauré un programme national de lutte contre l'hydatidose/échinococcose (PNLH). Ce programme a été initié en 2007, dont le but est de réduire de moitié l'incidence de l'hydatidose/échinococcose chez l'homme en 2015. Malgré les efforts, la réduction espérée n'a pas été atteinte. Une adaptation de ce programme est nécessaire pour combattre cette zoonose. À cet égard, la présente étude a pour objectif de cerner cette zoonose dans ses différents aspects et proposer des solutions pour améliorer ce programme.

Cette étude s'intègre dans le cadre d'un projet de recherche pour le développement (PRD) de la période qui s'étale de 2015 à 2020. Le projet est intitulé « Renforcement de la stratégie de lutte contre l'échinococcose zoonotique au Maroc : aspects vétérinaires, économiques et sociologiques ». Le projet vise à renforcer la stratégie de lutte existant à travers une approche multidisciplinaire. Il évalue en particulier une option de lutte innovante et prometteuse basée sur la

vaccination des ovins contre l'hydatidose/échinococcose combinée ou non à un contrôle parasitaire des chiens. Le projet vise aussi à proposer aux autorités compétentes et aux partenaires institutionnels concernés des recommandations socialement acceptables, économiquement justifiées et validées sur le plan sanitaire, pour l'amélioration de la stratégie de lutte existante. Le projet est financé par l'ARES-CCD (Académie de recherche et d'enseignement supérieur, Commission pour la Coopération au Développement). Notre travail est focalisé sur les aspects socio-économiques de l'hydatidose/échinococcose.

Notre travail a été mené en quatre étapes, dont chaque étape représente un chapitre de ce document. Ces chapitres sont présentés sous forme de quatre articles scientifiques, publiés ou en cours de soumission dans des revues scientifiques à comité de lecture. La première partie de notre étude avait comme but, une estimation monétaire et non monétaire des pertes causées par l'hydatidose/échinococcose chez l'homme et l'animal, à l'échelle nationale et provinciale. Le deuxième travail propose une méthode d'analyse participative pour identifier les obstacles et les enjeux du PNLH. Ensuite, on propose une analyse du PNLH via l'analyse de ses parties prenantes. Et finalement, une quatrième étude évalue l'acceptabilité et la faisabilité de la nouvelle stratégie de lutte contre l'hydatidose/échinococcose, basées sur la vaccination des ovins avec le vaccin EG95 et le traitement des chiens.

Revue bibliographique

1 Historique

Le kyste hydatique est une affection connue depuis l'Antiquité chez l'homme et chez les animaux. Au 4ème siècle avant Jésus-Christ, Hippocrate (460-370 AJ) a décrit de vraisemblables kystes hydatiques comme des tumeurs remplies d'eau, observées à l'autopsie du bétail et des porcs : *« quand le foie plein d'eau se rompt dans l'épiploon, le ventre se remplit d'eau et le malade succombe »* (Grove, 1990). De probables kystes hydatiques ont également été cités dans le Talmud qui mentionne la présence de kystes dans les viscères des animaux sacrifiés (Bourée and Bisaro, 2007). Au 17ème siècle, Francisco Redi évoque l'origine parasitaire de l'hydatidose et, en 1766, Pierre Simon Pallas a formulé l'hypothèse que le kyste hydatique est un stade larvaire de ténias. En 1805, Rudolphi décrit le tænia du chien et, à la fin du 19ème siècle, Von Siebold et Leuckart font la liaison entre la maladie du mouton, la maladie de l'homme et le ver intestinal du chien (Bourée and Bisaro, 2007; Tappe, Stich and Frosch, 2008).

2 Etude du parasite

2.1 Classification

Echinococcus granulosus est un parasite appartenant à (Thompson and Lymbery, 1995; Craig *et al.*, 2007) :

- Phylum des **Plathelminthes** : c'est un triploblaste acœlomique, aplati dorso-ventralement, au corps mou, muni d'un système d'excrétion protonéphrotique ;
- Classe des **Cestodes** : c'est un endoparasite sans intestin, dont le tégument externe est constitué d'un tissu syncytial (zone d'échange) portant des microtriches ;
- Sous-classe des **Eucestodes** : c'est un ver « ruban » (true tapeworm), dont la forme adulte est caractérisée par un corps allongé (strobile) constitué d'une suite linéaire d'organes de reproduction (proglottis), et une spécialisation de la partie antérieure en un organe d'attachement (scolex) ; ce ver est hermaphrodite avec un cycle biologique indirect;

- Ordre des **Tetracestode** ou **Cyclophyllidea** : le scolex porte 4 ventouses musculaires lisses et un rostellum généralement armé de crochets, le strobile est constitué de proglottis à différents stades de développement et clairement démarqués les uns des autres par une segmentation externe, les pores génitaux sont marginaux et simples, les œufs sont arrondis, non operculés, et contiennent des oncosphères non-ciliées à 6 crochets;
- Famille des **Taeniides** : le rostellum porte le plus souvent une double rangée de crochets, l'appareil génital est impair dans chaque proglottis et les pores génitaux marginaux alternent irrégulièrement ; les oeufs ont une coquille dure à striation radiale 16 (embryophore); les vers adultes vivent dans l'intestin grêle d'un carnivore, et l'hôte intermédiaire est toujours un mammifère ;
- Genre **Echinococcus** : la forme adulte ne mesure que quelques millimètres de long et comporte rarement plus de 5 segments ; elle est insérée profondément entre les villosités de l'intestin grêle de l'hôte définitif (cette localisation en profondeur lui est possible grâce à sa petite taille, tandis que les autres Taenias sont contraints de se fixer plus superficiellement) ; les larves ont une faible spécificité d'hôte et un grand potentiel de reproduction.

Six espèces sont reconnues dans le genre *Echinococcus* : *E. granulosus, E. multilocularis, E. oligarthus, E. vogeli, E. shiquicus* et *E. felidis* (Bronstein and Klotz, 2005). La présence d' *E. multilocularis* dans les pays au sud de la mer Méditerranée n'est pas confirmée (Deplazes *et al.*, 2017). *E. granulosus* est endémique en Afrique du Nord, dont le Maroc (WHO/OIE, 2002). Dans l'espèce *E. granulosus,* il existe plusieurs souches qui sont : la souche ovine commune (G1), la souche ovine tasmanienne (G2), la souche bubaline (G3), la souche bovine (G5), la souche équine (G4), la souche caméline (G6), la souche porcine (G7 et G9) et la souche des cervidés (G8 et G10) (Brunetti and Mccloskey, 2016). La majorité des infections humaines par *E. granulosus* sont attribuables la souche ovine commune (G1) qui est la plus pathogène pour l'homme, étant responsable de 88% des cas humains dans le monde (Alvarez Rojas, Romig and Lightowlers, 2014).

2.2 Cycle biologique

L'Echinococcus granulosus requiert deux espèces mammifères pour compléter son cycle (Figure 1). Les segments ovigères ou les œufs sont libérés dans les fèces de l'hôte définitif qui est un

carnivore. Les œufs sont ingérés par un hôte intermédiaire (ruminants) ou un hôte accidentel (l'homme). Le cycle est complet quand l'hôte définitif mange les tissus contaminés de l'hôte intermédiaire (HI) (Thompson and McManus, 2002). La forme adulte du parasite réside dans l'intestin grêle de l'hôte définitif (HD) qui peut être un chien ou un autre canidé. La reproduction est faite soit après autofécondation, soit plus rarement après fécondation croisée entre deux vers différents. Le dernier anneau ovigère se détache (tous les 7 à 12 jours) et gagne le milieu extérieur avec les matières fécales. Le prurit anal provoque chez le chien un réflexe de léchage, il récupère ainsi de nombreux œufs qui se retrouveront au niveau des papilles linguales et de la cavité buccale, puis par léchage, au niveau du pelage. Le chien (HD) se contamine en ingérant des organes d'animaux infestés par des kystes hydatiques (Aubry, 2013; Bronstein and Klotz, 2013). L'hôte intermédiaire s'infeste par voie buccale au moment de l'ingestion de l'herbe ou de l'eau souillées par les excréments des carnivores infestés par *E. granulosus*. Après ingestion, les œufs libèrent des embryons hexacanthes qui traversent la paroi intestinale pour gagner la circulation sanguine par la veine porte et ils peuvent ainsi atteindre divers tissus et organes. Les organes agissent comme des filtres et interceptent les embryons en migration (Villeneuve, 2003). Dans ces organes l'oncosphère se développe dans un kyste. Il se développe graduellement, produit des protoscolex et des vésicules filles qui emplissent l'intérieur du kyste (Bronstein and Klotz, 2013).

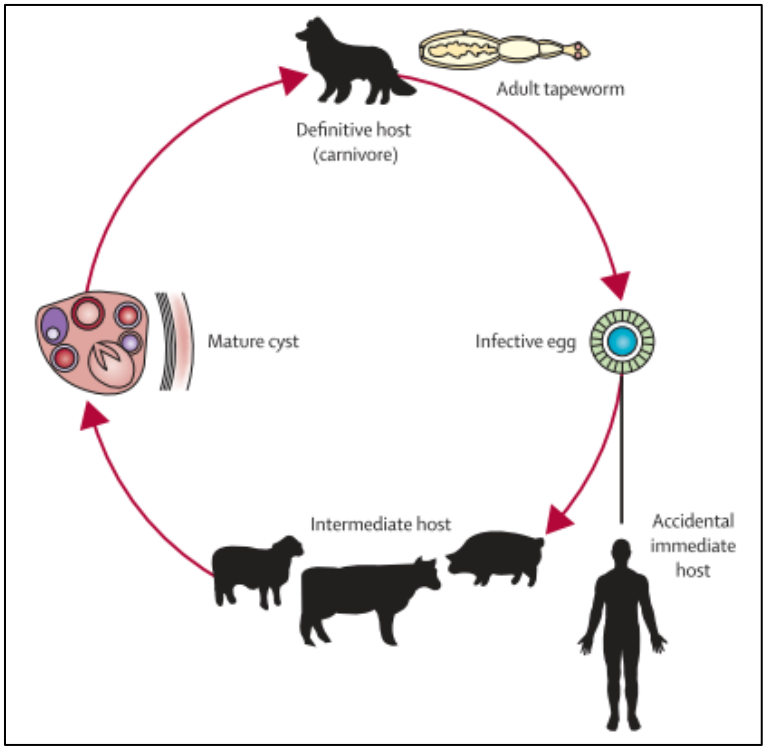

Figure 1: Cycle biologique de l'E. granulosus (Craig *et al.*, 2007)

2.3 Répartition géographique

L'échinococcose kystique est une zoonose cosmopolite (Figure 2), son risque est particulièrement élevé en zones rurales (WHO/OIE, 2002; Ito *et al.*, 2003). Dans les régions endémiques, les taux d'incidence de l'échinococcose kystique chez l'homme peuvent dépasser plus de 50 cas pour 100 000 personnes par année, et les niveaux de prévalence peuvent atteindre jusqu'à 5-10% des résidents de certaines régions d'Afrique de l'Est, d'Asie centrale, d'Argentine, du Pérou et de Chine (OMS, 2020). En ce qui concerne la prévalence de l'échinococcose kystique chez les animaux d'élevage, elle a été estimée à entre 20% à 95% chez les animaux abattus dans les abattoirs des zones endémiques d'Amérique du Sud (OMS, 2020). Les pertes économiques annuelles causées par l'échinococcose kystique ont été estimées à 14,7 millions USD en Tunisie, 200 millions USD en Espagne et 89 millions USD en Turquie (Fasihi Harandi, Budke and Rostami, 2012). L'espérance de vie corrigée de l'incapacité pour les maladies zoonotiques (zDALY) a été estimée en Tunisie, en Iran et en Espagne avec des valeurs respectives de 29,8, 27,2 et 2,86 années pour 100 000 personnes par an (Torgerson *et al.*, 2018).

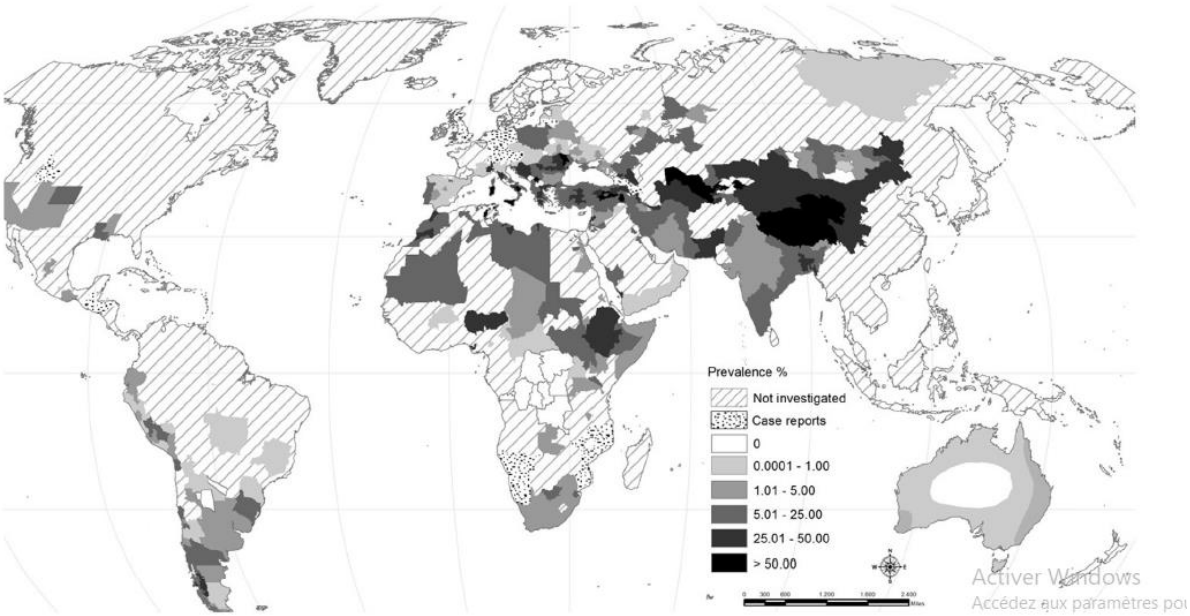

Figure 2: Répartition mondiale actuelle d'Echinococcus spp. *provoquant une échinococcose kystique chez les principaux hôtes intermédiaires domestiques* (Deplazes *et al.*, 2017)

3 Pathologie

3.1 Symptomatologie

3.1.1 Hôte définitif : le chien

La forme adulte du parasite reste asymptomatique et ne présente généralement aucun signe chez le chien. Cependant, des symptômes d'entérite ou du prurit anal en conséquence de la pénétration de segments ovigères dans les glandes anales, peuvent parfois être observés. En effet, chez le chien, des charges parasitaires allant jusqu'à 5000 et 6000 vers ont été rapportées sans pouvoir leur associer un signe clinique (Euzeby, 1971; Villeneuve, 2003).

3.1.2 Hôte intermédiaire : les ruminants

Chez l'hôte intermédiaire, les kystes se développent souvent lentement, parfois même sur plusieurs années et se caractérisent par l'absence de signes spécifiques même en cas de plusieurs kystes au niveau du foie et du poumon. En cas de localisation hépatique, on note des troubles digestifs et un ictère par compression des canaux biliaires. Une dyspnée et une toux rebelle sont relevées dans le cas de localisation pulmonaire. Dans certains cas, les kystes se rompent et libèrent des protoscolex et des vésicules filles qui se localisent ailleurs et continuent leur croissance (ANOFEL, 2019).

3.1.3 Hôte accidentel : l'homme

L'homme est un hôte accidentel d'*Echinococcus granulosus*, il s'infecte suite à l'ingestion d'aliments contaminés par les œufs libérés dans le milieu extérieur par l'hôte définitif. Une fois dans l'organisme, sous l'effet du suc gastrique, il y aura éclosion des œufs et libération de l'embryon hexacanthe qui se déplace généralement dans le courant sanguin jusqu'à ce qu'il colonise le foie, le poumon ou un autre organe. L'hydatidose/échinococcose humaine se caractérise par une longue période asymptomatique durant laquelle les kystes se forment, et peut même demeurer asymptomatique durant toute la vie si les kystes sont de très petite taille. Les symptômes sont secondaires à la compression qu'exerce le kyste sur les organes et/ou les tissus avoisinants. Cependant la rupture d'un kyste peut provoquer un choc anaphylactique entrainant la mort dans 5% des cas. Les symptômes varient en fonction de l'âge, de la localisation et de l'existence d'un kyste uniloculaire ou d'une polycystose (WHO/OIE, 2002; Eckert and Deplazes, 2004b).

3.2 Diagnostic

3.2.1 Chez l'hôte définitif : le chien

Plusieurs méthodes sont utilisées pour diagnostiquer la présence d'*E. granulosus* chez le chien, variant dans leurs performances de sensibilité et spécificité (tableau 1) (Craig and Larrieu, 2006). L'autopsie est une méthode très fiable permettant une évaluation quantitative de l'infection. Le traitement à l'arécoline est aussi utilisé. Cette molécule provoque une purge du tractus intestinal du chien, expulsant ainsi les formes adultes du parasite qui y sont présentes. La détection dans les matières fécales d'antigènes issus des activités de sécrétion-excrétion des vers adultes peut également se faire par ELISA. La détection d'anticorps sériques est aussi utilisée mais se heurte à une très faible réponse du système immunitaire, expliquant donc une faible sensibilité de la méthode.

Tableau 1: Comparaison de la sensibilité et la spécificité des différentes méthodes de diagnostic de l'échinococcose chez le chien (Craig and Larrieu, 2006)

Méthodes	Sensibilité %	Spécificité %
Autopsie	>90	100
Purge intestinale (arécoline)	50-70	100
Sérologie	35-70	>90
Détection de copro-antigènes	75-80	>95

3.2.2 Chez l'hôte intermédiaire : les ruminants

L'hydatidose ne présentant généralement pas de symptômes clairs chez les ruminants, le diagnostic est le plus souvent réalisé par inspection post-mortem, par la détection des kystes hydatiques dans les organes et tissus au niveau des abattoirs (Eckert and Deplazes, 2004c).

3.2.3 Chez l'homme

Chez l'homme, les kystes hydatiques peuvent être diagnostiqués par échographie, radiographie et diagnostic biologique (immunoélectrophorèse indirecte et ELISA) (WHO/OIE, 2002).

3.3 Traitement

3.3.1 Traitement chez les animaux

Seuls les canidés sont traités en raison du coût élevé pour les hôtes intermédiaires. Chez le chien le traitement se fait par chimiothérapie : auparavant, l'arécoline était utilisée et a été remplacée par le Praziquantel. Ce dernier est actif sur tous les stades adultes d'*Echinococcus granulosus* mais n'a pas une action ovicide (Thakur, Prezioso and Marchevsky, 1979). Dans le cadre d'un programme de contrôle, il est recommandé de traiter les chiens une fois toutes les 6 semaines car la période pré-patente est supérieure à 42 jours (Craig *et al.*, 2007).

3.3.2 Traitement chez l'homme

D'une manière générale les différentes options de traitement de kystes hydatiques chez l'homme sont la chirurgie, la technique PAIR (ponction-aspiration-injection-réaspiration), la chimiothérapie et la simple mise en observation (« watch and wait ») (Eckert and Deplazes, 2004a). La chirurgie reste le traitement le plus utilisé pour le traitement des kystes hydatiques.

En 2003, l'Organisation Mondiale de la Santé, à travers son groupe de travail sur l'échinococcose, a élaboré une classification des stades morphologiques des kystes hydatiques (WHO. IWGE, 2003). Cette classification permet de guider la prise en charge, orientant vers la chirurgie, la thérapie médicale, le traitement percutané ou l'approche «watch and wait» (WHO. IWGE, 2003). Malheureusement, l'utilisation de ces classifications est encore assez faible et la prise en charge de la maladie est souvent inappropriée, exposant les patients (et les systèmes de santé) à des traitements, des risques et des coûts inutiles (Nabarro, Amin and Chiodini, 2014). Au Maroc, le traitement de l'hydatidose est encore presque uniquement chirurgical, tandis que d'autres options

telles que le traitement percutané ne sont mises en œuvre que dans une minorité de cas (Chebli *et al.*, 2017).

4 Prévention

Depuis l'introduction du praziquantel, les programmes de lutte contre l'hydatidose se fondent en grande partie sur le traitement du chien tous les 45 à 90 jours. En théorie, un tel traitement de tous les chiens d'une région amènerait à l'interruption totale de la transmission (Larrieu *et al.*, 2013). Dans les régions où les moutons sont les hôtes intermédiaires, le renouvellement des moutons avec des animaux nés après l'interruption de la transmission entraînerait l'élimination d'*E. granulosus* (WHO/OIE, 2002). Cependant, là où le contrôle de l'hydatidose reposait sur un traitement fréquent des chiens avec du praziquantel, plus de 10 ans d'interventions intensives et obligatoires ont été nécessaires avant que la transmission de la CE n'atteigne un faible niveau et près de 30 ans ont été nécessaires pour obtenir l'éradication de la maladie (Craig and Larrieu, 2006). Dans d'autres zones où des activités de la lutte contre l'hydatidose ont été entreprises, l'infrastructure nécessaire pour traiter les chiens 8 à 12 fois par an n'a pas pu être maintenue durablement, les zones d'endémie étant souvent le plus pauvres (Larrieu and Zanini, 2012).

La vaccination des hôtes intermédiaires avec le vaccin recombinant EG95 pourrait être utilisé pour réduire le niveau de transmission d'*E. granulosus* et diminuer l'incidence des infections humaines (Bethony *et al.*, 2012). C'est un vaccin à base de la protéine recombinante EG95 extraite à partir de l'oncosphère de *l'E. granulosus*. En induisant des anticorps spécifiques contre l'oncosphère, le vaccin empêche la formation des nouveaux kystes hydatiques, mais il est peu efficace contre les kystes déjà établis (Torgerson and Heath, 2003; Larrieu *et al.*, 2013). Le vaccin s'est révélé d'une efficacité remarquable chez les moutons, assurant une protection presque totale (96-100%) (Larrieu *et al.*, 2015). Rappelons que la souche G1 du mouton est celle présentant le plus grand risque pour l'homme (Alvarez Rojas, Romig and Lightowlers, 2014). Ce vaccin s'est en outre révélé efficace même chez les bovins (Heath *et al.*, 2012). Des scénarios hypothétiques ont été étudiés pour l'utilisation du traitement des chiens et la vaccination des ovins. La conclusion était qu'un traitement anthelminthique des chiens nécessite un minimum de traitement tous les 3 mois, en supposant qu'au moins 60% des chiens seront traités ; la vaccination des moutons est efficace, à condition qu'une grande partie de la population soit vaccinée (plus de 90%) (Torgerson and Heath, 2003). Il est intéressant de noter que l'intervention la plus efficace était une combinaison de vaccination des moutons et de traitement anthelminthique (Torgerson and Heath, 2003).

Théoriquement, la combinaison de la vaccination des ovins et le traitement des chiens est apte à éliminer cette zoonose au bout de 15 ans (Torgerson, 2003).

5 Impact socio-économique

Les conséquences sociales et économiques de l'échinococcose kystique sont graves, en raison de sa morbidité, sa mortalité et ses pertes économiques à la fois chez l'homme et chez l'animal (Carabin *et al.*, 2005).

Chez l'animal, les pertes directes causées par l'hydatidose font suite aux saisies du foie, des poumons ou tout autre organe infesté, parfois même la carcasse entière. La destruction des abats saisis représente un coût supplémentaire. Ces pertes sont d'autant plus importantes lorsqu'il s'agit de saisies d'organes de haute valeur marchande notamment le foie (Moro *et al.*, 2011). Cette zoonose cause aussi des pertes de production chez les ruminants qui ne sont pas perceptibles pour les éleveurs. En effet, sur le vivant, le parasite peut entraîner en cas d'infestation grave un retard de la croissance des jeunes, une diminution de la fécondité d'où une réduction du taux des naissances, une baisse qualitative et quantitative de la production de viande, du lait et de la laine (Majorowski *et al.*, 2005).

L'impact chez l'homme comprend des coûts indirects associés à la perte de productivité et des coûts directs présentés par les coûts de la chirurgie, les soins médicaux, la mortalité (1-2% des cas) et l'absence au travail (Budke, Deplazes and Torgerson, 2006; Yang *et al.*, 2006). Les pertes économiques humaines ont été estimées à 193 529 740 USD et les pertes chez le bétail à 2 190 132 464 USD (Budke, Deplazes and Torgerson, 2006).

Une évaluation des mesures objectives et comparables de la santé de la population peut aider les décideurs d'un pays à identifier les priorités et à relever les défis (Kiadaliri and Aliasghar, 2018). Les années de vie corrigées de l'incapacité (DALY) peuvent être utilisées pour aider à une telle approche comparative du fardeau sanitaire, à prioriser le contrôle entre différentes maladies et à déterminer si une amélioration se produit au fil du temps. En 2017, le DALY pour toutes causes (au niveau mondial) a été estimé à 2 500 000 années de vie perdue (32 796,9 pour 100 000 personnes/année). Concernant l'échinococcose kystique, le DALY a été estimé à 100 années de vie perdue (1,3 pour 100 000 personnes/année), à comparer à des estimations de 45 000 années de vie perdue pour le paludisme (649,8 pour 100 000 personnes/année) et à 228 années de vie perdue pour l'hépatite C aiguë (3,3 pour 100 000 personnes/année) (Kiadaliri and Aliasghar, 2018). Notons

que la maladie à virus Zika ne présente qu'un DALY de 2,24 années de vie perdue par an (Kiadaliri and Aliasghar, 2018), la haute priorité accordée à son contrôle étant alors à lier à sa dimension épidémique et émergente. On peut se risquer à avancer ici qu'intervient probablement aussi une importance symbolique des symptômes provoqués, tenant à des malformations néonatales du système nerveux central.

Cette comparaison met en lumière à la fois l'importance du fardeau de l'échinococcose kystique à l'échelle mondiale mais explique aussi que cette maladie puisse apparaître comme faiblement prioritaire au regard d'autres maladies et appartienne à la catégorie de maladies tropicales négligées. Néanmoins, notre dernière remarque quant au virus Zika pointe vers d'autres enjeux de priorisation, qui ne sont guère représentés par les quantifications sous forme de DALY. C'est ainsi que le terme-même de « maladie tropicale négligée » vise à pointer l'importance de leur contrôle pour un motif de justice sociale et la pertinence de l'agrégation des fardeaux de ces maladies, diverses mais présentant des déterminants communs et donc des modes de contrôle communs (hygiène, éducation, accès à l'eau, contrôle des zoonoses du chien…).

6 Lutte contre l'hydatidose

Grâce au progrès des conditions de vie et de l'hygiène, le diagnostic et le traitement de l'hydatidose/échinococcose ont été améliorés chez l'homme et les animaux, ce qui a entrainé une réduction de la transmission dans certaines régions du monde, mais l'hydatidose/échinococcose persiste encore dans plusieurs pays, surtout le pourtour méditerranéen (Battelli, 2004; Moro and Schantz, 2007). L'hydatidose/échinococcose a été considérablement réduite dans plusieurs pays grâce à l'application à long terme de mesures de contrôle et de prévention basée sur le traitement vermifuge des chiens, l'éducation sanitaire et la surveillance du bétail et des populations humaines. Cependant, elle reste une grave zoonose négligée dans de nombreux pays à faibles et moyens revenus, et dans les régions pastorales, même dans les endroits où elle était auparavant à des niveaux faibles, en raison de problèmes économiques et manque de ressources qui a entrainé une réduction des programmes de lutte. Pour contrôler la transmission de ce parasite, un vaccin pour les ovins, appelé EG95, basé sur un antigène recombinant a été développé (Lightowlers *et al.*, 1996). L'intervention la plus efficace est la combinaison de la vaccination des moutons et le traitement anthelminthique des chiens (Torgerson, 2006). Théoriquement, la vaccination des moutons (par le vaccin EG95) associés à un traitement anthelminthique des chiens tous les 6 mois,

et la sensibilisation de la population permettraient le contrôle cette zoonose en environ 15 ans (Torgerson, 2003).

7 L'hydatidose/échinococcose au Maroc

7.1 Situation épidémiologique

Au Maroc, l'hydatidose/échinococcose sévit à l'état endémique dans la quasi-totalité du pays, elle constitue un problème de santé publique (Mansouri *et al.*, 2015). La prévalence de l'infection chez les animaux atteindrait jusqu'à 42,9% chez les bovins, 11% chez les ovins et 1,5% chez les caprins (El Berbri *et al.*, 2015). La prévalence d'infestation est élevée chez les chiens, allant de 23,5% à 38,8% et de 51,3% à 68,5% respectivement chez les chiens à propriétaire et les chiens errants (Amarir *et al.*, 2020). Chez l'homme, la prévalence de l'hydatidose a été estimée à 1,9% (Chebli *et al.*, 2017).

7.2 Programme national de lutte contre l'hydatidose (PNLH)

En réponse à cette zoonose, un programme national de lutte contre l'hydatidose/échinococcose a été mis en place en 2005. Avec le soutien de l'Organisation Mondiale de la Santé (OMS), un premier guide d'information et de directive sur la lutte contre l'hydatidose/échinococcose au Maroc a été élaboré en 2005 et initié en 2007, constituant ainsi un instrument de travail pour la structuration et la mise en place d'une stratégie nationale de lutte (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). Le guide était élaboré par le comité interministériel de coordination des activités de la lutte contre l'hydatidose/échinococcose (Ministère de la santé, Ministère de l'Agriculture et le ministère de l'intérieur). Il avait comme objectif de fournir les connaissances épidémiologiques nécessaires pour mieux comprendre la problématique que pose cette maladie en tant que problème de santé publique, il vise également à les familiariser avec les activités de prévention et de lutte contre cette zoonose, d'adopter les attitudes requises pour établir un diagnostic précoce pour la prise en charge thérapeutique et d'investir dans la promotion de la santé. Le PNLH a pour but de réduire l'incidence de 50 % en 2015 (Azzouzi, 2009). Selon le guide de lutte, la stratégie de lutte est basée sur trois axes principaux (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007) :

- *Axe I* : L'application de mesures de prévention visant à interrompre le cycle biologique du parasite;

- *Axe II :* Le dépistage précoce des personnes atteintes de kyste hydatique et leur prise en charge médicale ;
- *Axe III :* La disponibilité d'un arsenal législatif et réglementaire approprié.

7.2.1 Axe l: Interrompre le cycle biologique

Les activités liées à cet axe sont assurées par le Ministère de l'Agriculture (ONSSA) et le Ministère de l'Intérieur (Autorités et Collectivités Locales), elles exigent un investissement à long terme pour maintenir un programme de lutte efficace. Le contrôle de la maladie repose sur l'application de l'ensemble des mesures de prévention préconisées à trois niveaux (Figure 3) : L'hôte intermédiaire, l'hôte définitif et l'hôte accidentel. Cet axe vise à améliorer l'état général des abattoirs, le renforcement du contrôle des viandes, le contrôle de la population canine et la sensibilisation de la population.

Figure 3: les trois grand axes du programme de lutte contre l'hydatidose/échinococcose au Maroc

7.2.2 Axe II: dépistage précoce et traitement des malades

Cet axe relève exclusivement des services du Ministère de la Santé et concerne les personnes atteintes de kystes hydatiques. Il repose sur le dépistage précoce des cas et la prise en charge médicale. Lorsque le diagnostic radiographique ou échographique est confirmé, la personne atteinte est prise en charge à l'hôpital le plus proche et elle doit également faire l'objet d'une déclaration obligatoire selon la réglementation en vigueur. Des campagnes de sensibilisation

doivent être organisées. Elles ont pour but additionnel de sensibiliser la population sur les facteurs de risque associés à la maladie et les moyens de prévention.

7.2.3 Axe III: Arsenal législatif

L'existence de textes législatif et réglementaire avec des dispositions régissant certaines des activités de lutte, et leurs applications strictes constituent un instrument primordial de la lutte contre l'hydatidose/échinococcose. Dans ce cadre, un arrêté ministériel rendant la déclaration du kyste hydatique obligatoire a été publié au bulletin officiel au cours de l'année 2003 : Arrêté ministériel n° 1020-03 du 21 rabbi l 1424 (23 mai 2003) complétant l'arrêté du Ministre de la Santé Publique n° 683-95 du 30 chaoual 1415 (31 mars 1995) fixant les modalités d'application du décret royal n° 554-65 (La 17 rabbi 1 1387 (26 juin 1967) portant loi rendant obligatoires la déclaration de certaines maladies, dont l'hydatidose/échinococcose, et prescrivant des mesures prophylactiques propres à enrayer les maladies.

7.3 Organisation du programme national de lutte contre hydatidose/échinococcose

Trois ministères sont impliqués dans ce programme : le Ministère de l'Agriculture, le Ministère de l'Intérieur et le Ministère de la Santé (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). Selon le guide, un comité interministériel de lutte contre l'hydatidose/échinococcose est mis en place pour assurer l'application harmonieuse des actions figurant dans la circulaire, le suivi de l'état d'avancement du programme de lutte et son évaluation permanente, la coordination et la supervision nécessaires tant au niveau national que régional, l'information et la sensibilisation de la population.

Chaque ministère joue un rôle dans cette lutte (Figure 4). Le Ministère de l'Agriculture est présenté par l'ONSSA, il a comme fonction l'épidémio-surveillance de la maladie au niveau des abattoirs, la gestion des produits d'euthanasie (lorsque leur utilisation est décidée par la Commission préfectorale ou Provinciale de lutte contre la rage), l'information, l'éducation et la sensibilisation de la population sur la gravité de la maladie et les moyens de prévention et de lutte. Le Ministère de l'Intérieur est présenté par les collectivités locales. Les actions des collectivités locales sont assurées à travers les bureaux municipaux d'hygiène (BMH), notamment la lutte contre les chiens errants, l'aménagement des abattoirs existants (approvisionnement en eau potable, installation de clôtures, fosses septiques…), les constructions futures des abattoirs, le renforcement de la lutte contre l'abattage clandestin, l'éducation et la sensibilisation de la population. Le Ministère de la

Santé, représenté par la Direction de l'épidémiologie et de lutte contre les maladies (DELM) a comme rôles la surveillance épidémiologique de l'hydatidose/échinococcose afin d'évaluer de manière efficace et continue les actions de lutte entreprises. La délégation de santé régionale se charge de la surveillance des indicateurs épidémiologiques au niveau local et de la convergence de toutes les données à la DELM. Les hôpitaux s'occupent de la prise en charge dans ses structures des personnes atteintes de kyste hydatique et la standardisation des techniques de diagnostic préconisées.

Des commissions ont été créés pour veiller à l'application du programme au niveau provincial, coordonner les actions des services concernés, suivre l'état d'avancement, transmettre régulièrement les informations et améliorer les textes réglementaires en cas de nécessité.

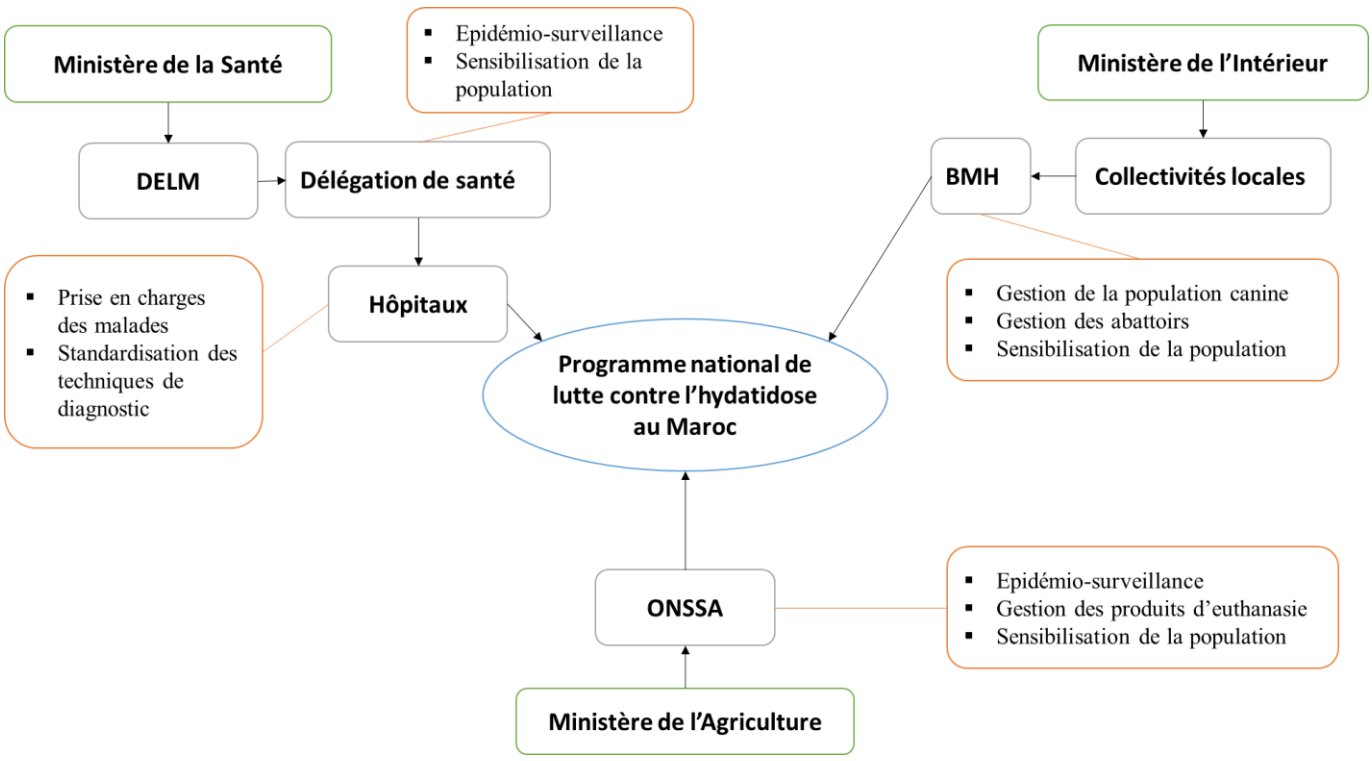

Figure 4: ***Organisation du programme national de lutte contre l'hydatidose/échinococcose au Maroc.*** *DELM : Direction Epidémiologie et Lutte Contre Maladies; BMH : bureau municipal d'hygiène; ONSSA : Office national de sécurité sanitaire des produits alimentaires. Cadrant vert: les ministères responsables du programme; cadrant noir: institutions affiliées; cadrant rouge: rôles dans le programme; Flèche: sens de la hiérarchie.*

7.4 Persistance de l'hydatidose/échinococcose au Maroc

Jusqu'à la rédaction de ce manuscrit, aucune évaluation officielle du PNLH n'a été faite. Mais les études menées dans différentes régions du Maroc ont montré une persistance de l'hydatidose/échinococcose chez l'homme et l'animal (I El Berbri *et al.*, 2015; Mansouri *et al.*, 2015; Chebli *et al.*, 2017). Les causes de persistance de cette zoonose au Maroc sont multiples, dont le nombre de chiens élevé, spécifiquement les chiens semi-errants, les comportements à risque de la population locale, les infrastructures et des pratiques d'abattoir (Ikhlass El Berbri *et al.*, 2015). La mauvaise compréhension du cycle de vie du parasite est un autre facteur majeur de persistance de la maladie, car elle entraine des comportements à risque liés aux pratiques d'élevage ovin et à l'abattage à domicile, la garde de chiens et la mauvaise gestion des abats (Bardosh *et al.*, 2016; Thys *et al.*, 2019). Dès lors, une adaptation du PNLH est nécessaire pour contrôler cette zoonose.

8 Conclusion

L'hydatidose/échinococcose est une zoonose préoccupante dans le monde entier, surtout dans les pays à faibles et moyens revenus et là où l'élevage pastoral tient un place importante. Elle présente un problème majeur de santé publique et d'économie lié aux pertes de productions chez le bétail, les saisies au niveau des abattoirs et aux pertes de jour de travail chez les individus infectés. Au Maroc, cette zoonose représente un lourd fardeau en termes de santé humaine et animale. Plusieurs facteurs contribuent à la persistance de la maladie au Maroc, particulièrement le faible niveau d'hygiène, l'ignorance de la cause de la maladie, son mode de transmission et les moyens de prévention et l'absence de programme de gestion de ces populations. Malgré les efforts menés dans le cadre de programme national de lutte contre l'hydatidose/échinococcose au Maroc, le pays est toujours endémique et ne semble pas voir la maladie régresser. Ceci pose la question de l'efficacité de ce programme et des voies de son amélioration en prenant en compte tous les facteurs économiques, épidémiologiques et socio-culturels.

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Section études

Chapitre 1

Impact économique de l'hydatidose/échinococcose au Maroc

Cette étude a été publiée dans la revue « **PLOS Neglected Tropical Diseases »**

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Préambule

Le but de cette première partie de l'étude est d'estimer l'impact économique de l'hydatidose/échinococcose dans toutes les régions du pays. Nous avons combiné des méthodes financières et non financières pour estimer le fardeau de cette zoonose chez l'homme et l'animal. Cette étude documente et agrègent en une estimation les coûts attribuables à ce parasite au Maroc. Les résultats de cette étude peuvent être utilisés pour alimenter les processus de prise en compte politique de cette maladie parmi les priorités nationales. Les informations générées présentent ainsi un intérêt pour aborder les décideurs, les donateurs potentiels et le personnel des services de santé humaine et animale en vue d'une promotion plus efficace de la lutte contre l'hydatidose/échinococcose.

The socio-economic burden of cystic echinococcosis in Morocco: a combination of estimation methods

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Abstract

Cystic echinococcosis (CE) is a major zoonosis in Morocco despite the launch of a national control programme in 2005. As its economic consequences have not been studied yet in Morocco, this study estimated CE impact in terms of monetary losses, disability-adjusted life years (DALY), and DALY for zoonotic diseases (zDALY) in the entire country and in specific regions for the 2011 to 2014 period. The direct monetary losses were related to organ seizure from infected animal in slaughterhouses, and to healthcare expenses as well as lost wages for infected humans. Animal production losses concerned milk yield, fertility, carcass weight, and wool production. Losses due to human infection were also composed of disability and productivity losses at work. Monte Carlo simulations were used to estimate monetary losses and zDALY values. . Nationwide, the estimated DALY was 0.5 years per 100,000 persons per year, and the zDALY was 55 years per 100,000 persons per year. Total yearly losses were estimated at 73 million USD (54-92 million USD). However, losses differed significantly among regions. Most of the economic losses consisted of unperceived consequences, i.e. decreased animal production and reduced productivity of asymptomatic individuals. Future studies should determine the socioeconomic and epidemiological

factors underlying the differences in economic losses among regions to develop better adapted control programmes.

Author Summary

Cystic echinococcosis (CE) is a major neglected zoonosis in Morocco, despite the launch of a national control programme in 2005. The first study on CE in Morocco dates back to 1924. However, no evaluation of economic losses was made until now. The present study estimated the economic losses caused by CE in Morocco, at the national and regional scale, by combining financial and non-financial methods. Estimation of the direct and indirect losses caused by CE infection in humans and livestock (sheep, cattle, goats and camels) highlighted the important disease burden nationwide, amounting to 0.07% of Morocco Gross Domestic Product. The combination of methods brought information on the different CE-linked economic losses, including the unperceived consequences. These results indicate that the national CE control strategy did not result in a decrease of the disease burden, which calls for its evaluation and improvement.

Keywords: Cystic echinococcosis (CE); Economic losses; zDALY; Morocco.

1 Introduction

Cystic echinococcosis (CE) is a parasitic zoonosis caused by *Echinococcus granulosus*. The cycle includes canids as definitive host, and herbivores and omnivores as intermediate hosts. Intermediate hosts are infected through the ingestion of *E. granulosus* eggs released in canids' faeces. Then, cysts are formed in various organs of the intermediate host, particularly liver and lungs. Canids are infected by consuming infected intermediate hosts with cysts, and will develop the adult form in their intestinal tract. Humans are an accidental intermediate host. The risk is particularly high for rural populations, where dogs are kept for herding and people have low standards of living. CE represents a public health issue worldwide (Budke, Deplazes and Torgerson, 2006).

In Morocco, CE in humans is a notifiable disease. However, the surveillance system, supervised by the Ministry of Health (Ministère de la santé et l'OMS, 2016), is mainly based on recording the patients undergoing surgery for hydatid cysts in public hospitals (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). For the periods 1980–1992 and 2003–2008, 23,512

patients who underwent surgery for hydatid cysts were recorded in the Ministry of Health registry, and the mean annual incidence of surgical cases increased from 3.6 to 5.2 per 100,000 persons from 1980 to 2008 (Derfoufi *et al.*, 2012). The most affected regions are Meknes-Tafilalt and Chaouia-Ouardigha (Derfoufi *et al.*, 2012). More recent data provided by the ministry of Health on the annual incidence of human CE reported 7,536 operated cases for the period from 2009 to 2014, and the mean annual incidence of surgical cases decreased from 5.3 to 2.2 per 100,000 person from 2009 to 2014. However, ministerial data are underestimating the true prevalence of infection, because many infected individuals do not present symptoms, or because part of people with symptomatic disease will not be treated by surgery, and therefore will not be recorded in the Ministry of Health registry (Chebli *et al.*, 2017). Almost all hydatid cysts reported in Morocco (95%) are diagnosed by ultrasound examination (Hidki, 2013) and the studies on CE prevalence in humans are rare and are often focused on rural areas (Mansouri *et al.*, 2015). In 2014, an ultrasound screening in the Mid Atlas reported that the prevalence of abdominal CE was 1.9%. Moreover, 52.1% of them were asymptomatic (Chebli *et al.*, 2017). The World Health Organization Informal Working Group on Echinococcosis (WHO-IWGE) implemented a classification in clinical categories to guide the management of patients with CE (surgery, medical therapy, percutaneous treatment, and "watch and wait" approach) (WHO. IWGE, 2003). However, in Morocco, CE treatment is almost always surgical, while other options, such as percutaneous treatment, are rare (Derfoufi *et al.*, 2012).

Data on animal CE in Morocco come from records established by the veterinary services of slaughterhouses, CE being also a notifiable disease in animals (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). For the period 2001-2004, CE prevalence based on this post-mortem inspection was estimated at 23.0% in cattle, 12.0% in camels, 10.6% in sheep, and 1.9% in goats (Azlaf and Dakkak, 2006). Data for 2014 provided by the Ministry of Agriculture show that CE prevalence at slaughterhouses was 12.4% in cattle, 8.7% in camels, 8.4% in sheep and 4.7 % in goats. In all species, infection is reported more frequently in older animals (Azlaf and Dakkak, 2006; I El Berbri *et al.*, 2015). This could be mainly explained by the cumulative exposure risk, as well as the time required for the development of hydatid cysts. Indeed, smaller microscopic and early cysts may escape inspection (I El Berbri *et al.*, 2015). Therefore, data from slaughterhouses would underestimate the true CE incidence in farm animals throughout Morocco, because young animals are more frequently slaughtered (Dakkak and Ouhelli, no date). Moreover,

animals slaughtered at home, a common practice in Morocco, and animals slaughtered during the feast of sacrifice (i.e., 5 million small ruminants, one per household) are consumed without any sanitary control (Sarter, 2006).

In 2004, Morocco has set up a national programme of CE control by creating an inter-ministerial CE control committee that involved the Ministry of Agriculture, the Ministry of Health and the Ministry of the Interior. In 2005, a monitoring guide was developed and the programme was launched in 2007, when CE notification became mandatory (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). This programme is based on three main strategic axes: i) in animals, stopping the parasite life cycle, protecting the livestock, and controlling the dog population; ii) in humans, early detection and treatment of individuals with hydatid cysts; and iii) elaboration of an appropriate legislative and regulatory arsenal (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). The aim of this program was to decrease by 50% the incidence in human (2.8 cases per 100,000 person in year) (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). However, the implementation of integrated control measures has been extremely difficult due to inter-ministerial collaboration issues, and only the notification system of patients undergoing surgery for CE has been put in place, which does not fit the goal of early detection (Chebli *et al.*, 2017). Moreover, no official evaluation of the program has been carried out yet. The causes of CE persistence in Morocco are manifold, including the slaughterhouse practices, and the poor understanding of the parasite life cycle by the population that leads to risky behaviors (Bardosh *et al.*, 2016; Thys *et al.*, 2019). Indeed, the slaughterhouse infrastructure and their practices are unsatisfactory, and dogs (owned and stray) have access to infected organs (Ikhlass El Berbri *et al.*, 2015; Bardosh *et al.*, 2016). A study conducted in the Middle Atlas showed a high prevalence of CE infestation in dogs, ranging from 23.5% to 38.8% in owned dogs and from 51.3% to 68.5% in stray dogs (Amarir *et al.*, 2020).

Due to the high disease burden still observed despite this national programme, corrective policies and actions are needed. In this context, precisely assessing CE socio-economic impacts is essential (Torgerson *et al.*, 2018). Indeed, CE burden is important due to its morbidity, mortality, and socio-economic losses (Carabin *et al.*, 2005). This can be estimated using two main methods: disability-adjusted life years (DALY) and monetary losses (Budke *et al.*, 2004). Monetary losses concern humans (healthcare expenses, loss of vitality and health (Wang *et al.*, 2012)) and livestock (organ

seizure and reduced animal production in terms of carcass weight, milk yield, fertility, and wool (Majorowski *et al.*, 2005)). For example, a study conducted in Turkey showed that the presence of hydatid cysts reduced the average carcass price by 4.4% (Umur, 2003). CE economic importance in slaughtered animals results from the seizure of liver, lungs or any other infected organ, sometimes even the whole carcass (Comité interministériel de lutte contre L'Hydatidose, 2007).

DALY is a non-financial method to estimate disease burden in humans, and is considered the reference disease-burden metric by the WHO (Carabin *et al.*, 2005). DALY calculation aggregates the loss in healthy life years by considering the adjusted life years lived with disability (YLD) and the years of life lost due to premature mortality (YLL) (Devleesschauwer *et al.*, 2014). However, in the case of zoonosis, DALY does not take into account the burden caused by animal infection (Palmer *et al.*, 2011). Therefore, the method has been modified for zoonotic diseases, estimating the so-called zDALY (Torgerson *et al.*, 2018). Specifically, this metric includes also the animal loss equivalents (ALE) that is calculated by quantifying the livestock losses divided by the national income value. ALE reflects the "labour time lost" due to a zoonotic disease (Shaw *et al.*, 2017).

In the prospect of informing future policies, the aim of the present study was to use financial and non-financial methods to estimate CE burden in Morocco, at national and subnational scales, to enable public health policy-makers to optimally allocate the limited resources and to design effective control campaigns.

2 Material and methods

2.1 Ethics Statement

All data used in this study were in the form of aggregated data that cannot be associated with any specific individual. Therefore, neither consent nor ethical clearance was needed for this study.

2.2 Study area

This study covered the entire territory of Morocco, and included also a comparison of its regions, as defined by the National Office for Food Safety (ONSSA) (Fig.), because all data provided by the different ministries are presented by region. Moreover, data were also collected in Khénifra (Meknes Tafilalet region), the city with the highest CE incidence in humans in Morocco.

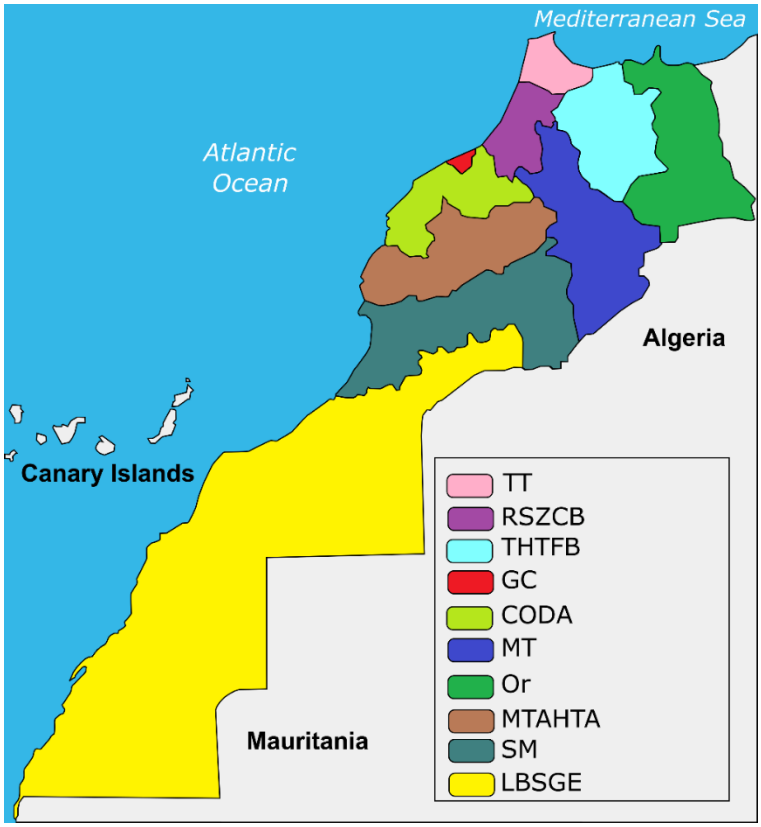

Fig. 1: ***Regions of Morocco according to ONSSA****. CODA: Chaouia Ouardigha Doukkala Abda; GC: Grand Casablanca; LBSGE: Laayoune Boujdour Sakia El Hamra Guelmim Essmara; MT: Meknes Tafilalet; MTATA: Marrakech Tensift Al Haouz Tadla Azilal; Or: Oriental; RSZCBH: Rabat Sale Zemmour Zaer Chrarda Bni Hssen; SM: Souss Massa Draâ; THTFB: Taza Alhoceima Taounate Fes Boulemane; TT: Tanger Tetouan (Adapted from Wikimedia commons: https://commons.wikimedia.org/wiki/File:Morocco_Regions_97-11_numbered.svg)*

For this study, which was started in 2016, data for the 2011 to 2014 period were collected because they were available in digital format for all regions.

2.3 Economic losses for people with CE

This study estimated the economic losses for people who underwent surgery for CE and also for asymptomatic people. The Ministry of Health provided the incidence of patients with CE who underwent surgery in public-sector hospitals per region and per year. Only the costs related to surgical treatment was estimated because CE treatment in Morocco is almost only surgical (Derfoufi *et al.*, 2012). Losses for asymptomatic undiagnosed people were based on productivity losses. Data on different surgical interventions cost were extracted from the records of the hospital

of Khénifra (capital of Mid Atlas) (Fig. 2). To calculate the additional costs related to hospitalization (travel costs, food, etc.), patients who underwent surgery at Khénifra hospital (n=14) were contacted and asked to fill in a questionnaire (Table 1).

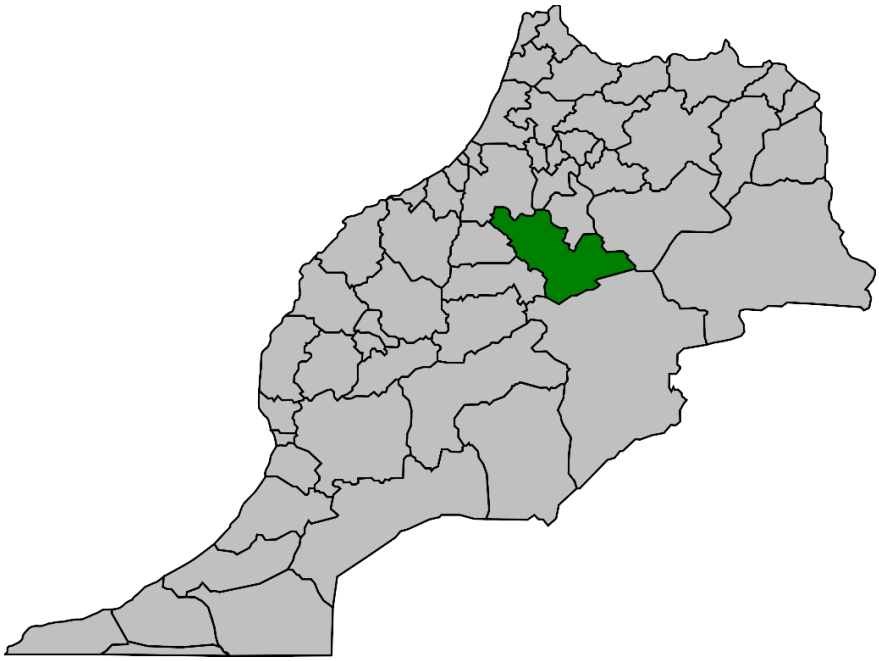

Figure 2: **Khénifra province (in green)**. *(Source: Wikimedia commons*: https://commons.wikimedia.org/w/index.php?search=province+de+khenifra&title=Special%3ASearch&go=Continuer&uselang=fr&ns0=1&ns6=1&ns12=1&ns14=1&ns100=1&ns106=1#/media/File:Khenifra_in_Morocco.png)

Table 1: Questionnaire sent to patients with CE who underwent surgery at Khénifra hospital to determine the additional costs

Number of accompanying persons
Transport cost per person
Cost of lost work days for the accompanying person(s)
Costs before surgery
-Laboratory/imaging analyses
-Drugs
-Diagnosis-related exams
- Lost income

In Morocco, 84% of hydatid cysts are localized in liver and 12% in lungs (Derfoufi *et al.*, 2012), followed by kidney, peritoneum, spleen and pancreas, which are included in the abdominal surgery category (Hidki, 2013). Therefore, our estimates were based on the fact that 88% of patients had

abdominal surgery and 12% had thoracic surgery. The cost related to hospitalization covered medical fees (e.g. drugs, diagnosis-related exams, and surgery), non-medical expenses (e.g. accompanying family member, transportation, accommodation and food), workdays lost before hospitalization, and additional costs for postoperative complications, if applicable. Because of the absence of post-surgery course information, the post-surgery costs were based on literature data indicating the absence of post-surgery complications for 97.06%, post-surgery complications for 0.12%, recurrent illness for 0.31%, and death for 0.2% of patients who undergo surgery for CE in Morocco (Hidki, 2013).

According to Khénifra hospital records, the mean hospital stay was 8.15 days (1 - 34 days), and the post-surgery leave prescribed ranged from 10 to 30 days. The estimated loss of work days ranged from 1 day to 1 year in the event of death (Fasihi Harandi, Budke and Rostami, 2012). A loss of 100% of daily wages was assumed for patients during the post-surgery leave. In the case of unemployed people, the loss of workdays was equal to zero. The unemployment rate was 15.2% for men and 30.5% for women in urban areas, and 8.3% for men and 26.2% for women in rural areas (HCP, 2014). CE frequency was 62.52% in rural areas and 37.48% in urban areas (Hidki, 2013). The loss of work days was estimated from the gross national income (GNI) per capita in Morocco that shows drastic differences between women and men (International Monetary Fund, 2017). Given the absence of data on GNI per capita by gender, this difference was estimated from data published by the United Nations Development Program (UNDP). In 2013, the estimated GNI per capita in Morocco, based on purchasing power parity (PPP) (Constant 2011 PPP USD), was 10,692 USD for men and 3,215 USD for women (UNDP, 2013b, 2013a). Therefore, the GNI per capita was 46.56% for women and 154.84% for men of the GNI per capita in Morocco (i.e. 6,905 USD) (UNDP, 2014).

When the operated patient was a child or an elderly person, a loss of 30% of the income of one relative was applied for the hospitalization period, based on the assumption that one family member devoted part of his/her time to take care of the hospitalized person (Majorowski *et al.*, 2005; Fasihi Harandi, Budke and Rostami, 2012). In Morocco work starts from the age of 15, therefore, the 15-60 age group was considered the working age group (HCP, no date). Figure 3 presents the diagram used to estimate the GNI loss per capita. The distribution of cases by age and gender was estimated using data extracted from the Khénifra hospital records.

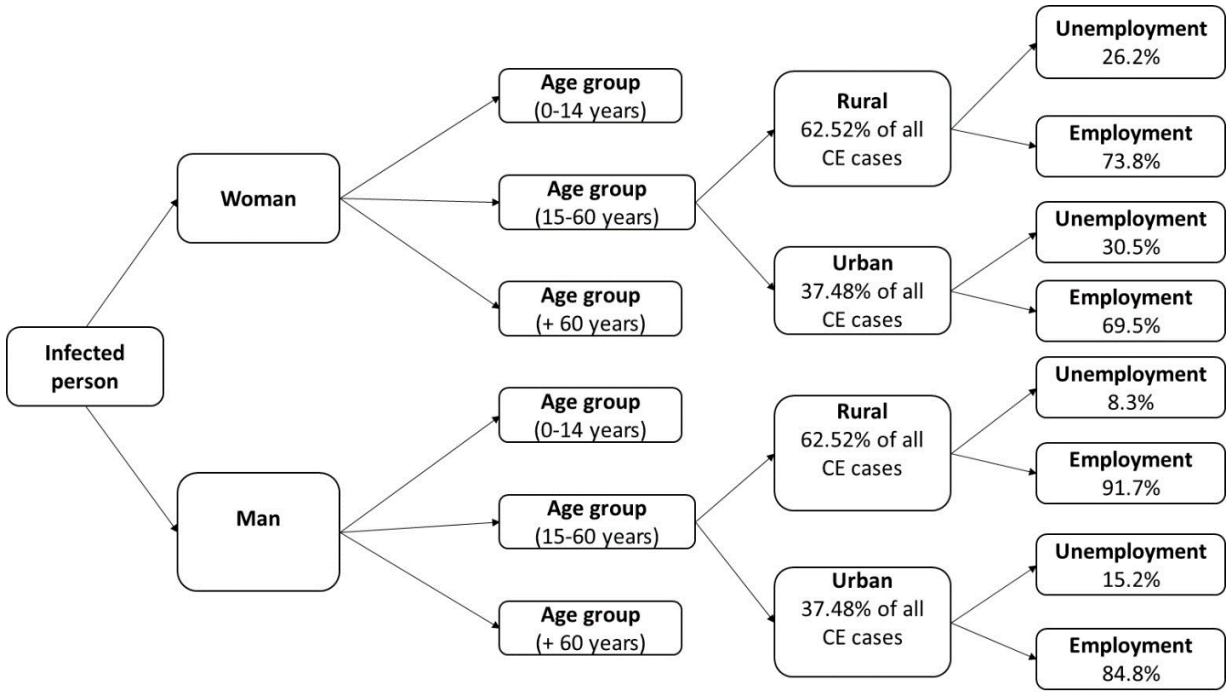

Figure 3: Schematic description of how the loss of workdays was estimated in function of the patient age group and environment features.

The loss of productivity by patients undergoing surgery for CE and asymptomatic individuals was estimated from literature data at 2%, with a uniform distribution from 0% to 4% (Torgerson, Dowling and Abo-Shehada, 2001; Moro *et al.*, 2011). Being undiagnosed, this number of cases is not known in Morocco. Therefore, the number of undiagnosed cases was estimated using the available data on abdominal CE from the ultra-sound screening-based study by Chebli and co-workers in 2017, who found a prevalence of 2.6% in Ifrane and 1.3% in El Hajeb (Mid Atlas) (Chebli *et al.*, 2017). No corresponding data could be found for pulmonary cases in Morocco nor in neighboring countries. The incidence of patients with CE who underwent surgery, recorded by the Ministry of Health for the same period, was 18 in Ifrane and 10 in El Hajeb. The prevalence of asymptomatic cases was then estimated as follows:

$$\textbf{Prevalence of asymptomatic cases} = \left[\frac{(\text{Prevalence} * \text{Observed population}) - \text{Surgical Incidence}}{\text{Observed population}}\right] * 100$$

and ranged from 1.9% to 2.2%. Due to the uncertainty associated with this estimate, a triangular distribution was used, with a minimum value of 0%, a maximum value of 2.2%, and a probable value of 2.05% (the mean of the extrapolated values). The same diagram presented in Figure 3 was

used to estimate the productivity losses linked to asymptomatic CE, by taking into account age (15 to 60 years), gender (man/woman), area (rural/urban), and unemployment rate.

2.4 Livestock losses due to CE

The species that were considered here are sheep, cattle, goats and camels (i.e. the most common species in the country). CE prevalence, organ or carcass seizure due to CE, number of slaughtered animals, and number of animals by sex and age were provided by ONSSA and HCP. Data on the national production of milk, meat and wool were supplemented with data from the World Bank website. The CE-linked yield reduction rates (Table 2) used for the calculation of each parameter were obtained from literature data (Torgerson, Carmona and Bonifacino, 2000; Battelli, 2009; Benner *et al.*, 2010; Singh *et al.*, 2014). The price of milk was provided by the largest milk collector in Morocco (Centrale laitière). The Khénifra Butchers Union provided the mean price of meat and offal (liver and lung). The two largest Moroccan associations of sheep and cattle farmers provided the prices of new-born calves/lambs and wool.

Table 2: Percentage of animal product reduction caused by CE

Parameter	Reduction rate (%)	Source
Cattle		
Meat	2.5-10%	(Torgerson, Carmona and Bonifacino, 2000)
Milk	2.5-5%	(Torgerson, Carmona and Bonifacino, 2000)
Fertility	9.9-12.1%	(Torgerson, Carmona and Bonifacino, 2000)
Sheep		
Meat	5-20%	(Torgerson, Carmona and Bonifacino, 2000; Battelli, 2009)
Wool	10-40%	(Torgerson, Carmona and Bonifacino, 2000; Battelli, 2009)
Fertility	9.9-12.1%	(Torgerson, Carmona and Bonifacino, 2000; Battelli, 2009)
Goats		
Meat	5-20%	(Battelli, 2009)
Fertility	9.9-12.1%	(Battelli, 2009)
Camels		
Meat	2.5-10%	(Benner *et al.*, 2010; Singh *et al.*, 2014)

Table 3 summarizes the formulas used to estimate animal production losses. Specifically, offal losses were calculated for two organs (lung and liver: the most frequently seized organs). For cattle, sheep and goats, the percentage of lung and liver seized was extrapolated from the Khénifra slaughterhouses' records. For camelids, data were retrieved from a study on CE prevalence in camels in Mauritania (Ahmed and Schneegans, 2010), a country that borders the Moroccan region

where camel farming is concentrated. The average production of each parameter per animal (milk, wool, meat and new-born) was estimated by dividing the type of animal production on the number of animal concerned.

Table 3: Formulas used to estimate animal product losses (milk, wool, meat and fertility)

Type of product	Formula
Percentage of offal losses	• Total offal losses(##) = liver losses + lung losses • Percentage of liver losses(##) = (liver losses/total offal losses)*100 • Percentage of lung losses(##) = (lung losses/total offal losses)*100
Production	• Average weight per carcass(^) = annual carcass production/number of animals slaughtered in that year • Average annual milk yield per cow(^) = total milk production of the country/number of dairy cows • Average annual wool production(^) = total wool production in the country/number of sheep • Mean number of new-borns per female(^) = total number of births/number of breeding females
Monetary losses due to offal losses	• Liver losses = (total seizures due to CE(#) * Percentage of liver losses)* price per kg of liver • Lung losses = (total seizures due to CE(#) * Percentage of lung losses)* price per kg of lung • Total losses = Liver losses + Lung losses
Meat losses	• Weight losses = ((Average carcass weight × percentage of carcass weight reduction(###))* number of infected animals(#))* price per kg of meat
Milk losses	• Number of infected cows = number of dairy cows(#) * prevalence of CE(#) • Milk losses per cow = production of milk per cow * rate of reduction in milk production due to CE(###) • Total milk losses = (number of infected cows * losses in milk per cow)* milk price per litre
Wool losses	• Infected sheep = number of sheep(#) * prevalence of CE • Wool losses per animal = average wool production per animal * percentage of wool production reduction(###) • Total wool losses = (infected sheep * losses of wool per animal)* price of wool
Decreased fertility	• New-born losses = (((number of breeding females(#) * CE prevalence) * average number of new-borns per female) * percentage of fertility reduction(###)) * New-born price
(#): ministerial data; (##): estimated from Khénifra records; (###): literature data; (^): estimated from ministerial data	

For the young animals, the prevalence of CE infection corresponds to the prevalence of slaughterhouses. For the adult animals (sheep and goats over 2 years old, and cows over 3 years old), analyses were carried out using a minimum prevalence that corresponded to CE prevalence at slaughterhouses, and a maximum prevalence from literature data (56% in cattle, 40% in sheep, 20% in camels and 7% in goats) (Azlaf and Dakkak, 2006). To estimate the average weight per carcass, which relates to the quantity of meat lost and therefore to slaughtered animals, the prevalence of CE at slaughterhouses was used. Milk losses were only established for cattle and

wool losses were estimated for sheep, because other species are not significantly exploited for milk and wool production in Morocco. Losses associated with decreased fertility were estimated as the number of lost new-borns, which are sold at birth. Decreased fertility was not estimated for camels due to the lack of data.

2.5 DALY and zDALY

The DALY represents the sum of the YLL and of the YLD values. In the zDALY, ALE is added to the DALY value (Torgerson *et al.*, 2018). ALE is the time lost to compensate for the monetary losses of livestock (i.e. the number of years of individual work needed to produce the amount lost).

2.5.1 DALY estimation

In accordance with other studies, YLL and YLD were considered as resulting only from surgical cases, and asymptomatic cases were considered as not having any significant impact on these two dimensions (Budke *et al.*, 2004). DALY was calculated as follows (Murray, 1994; Budke *et al.*, 2004):

$$-\left[\frac{DCe^{-\beta a}}{(\beta+r)^2}\left[e^{-(\beta+r)(L)}\left(1+(\beta+r)(L+a)\right)-(1+(\beta+r)a)\right]\right]$$

Where **D** is the disability weight**, C** the age weighting correction constant (C = 0.16243), **β** the age weighting parameter (β = 0.04), **r** the discount rate (r = 0.03), **a** the age at disease onset, **L** the disability duration or time lost due to premature death, and e = 2.71. (Budke *et al.*, 2004). In the absence of complications, D = 0.200 and L = 1 year; in the case of postoperative complications, D = 0.239 and L=5 years; in the case of recurrent illness, D= 0.809 and L=5 years; and in the case of death after surgery, D=1 and L=7.25 (Budke, Deplazes and Torgerson, 2006). The age at disease onset (a) was extrapolated from the Khénifra hospital records and corresponded to the age at surgery. L was estimated from the literature (Budke, Deplazes and Torgerson, 2006) due to the absence of data.

2.5.2 ALE estimation

ALE was estimated by dividing the monetary value of livestock losses by the GNI per capita (Torgerson *et al.*, 2018) obtained from the World Bank database.

2.6 Conversion of total economic losses into DALY-equivalent

To allow for comparisons of the actual DALY with a DALY-like value including the productivity losses for asymptomatic CE patients, a conversion was proposed applying the same calculation as that performed to convert animal economic losses into ALE. Hence, the total annual economic losses caused by CE in humans and animals was converted into lost years by dividing the monetary value of these losses by the GNI for the corresponding year.

2.7 Data analysis

To account for the uncertainty of the proposed estimates, stochastic methods were used for the overall calculations. The 95% confidence intervals for the total loss were computed by running 100,000 Monte Carlo simulations with the Python Programming Language (version 2.7) and by taking the minimum, maximum, mean, median, the 2.5 - 97.5 percentiles and standard deviation (SD). The choice of distributions was based on the literature, as already detailed here above for several parameters (Singh *et al.*, 2014). Regarding CE prevalence for young animals, a beta probability distribution was chosen, with alpha and beta parameters based on the slaughterhouse data in the different regions of Morocco. Alpha was equal to the number of CE cases + 1, and beta to the number of all examined animals minus the number of CE cases + 1. For adult animals, a uniform distribution was used, with a minimum value that corresponded to the prevalence in the slaughterhouses, and a maximum value that corresponded to CE prevalence in old animals in the literature (Azlaf and Dakkak, 2006). Triangular distributions were used for product loss parameters (i.e. fertility, carcass weight, meat price, milk production, milk price, offspring price, wool production, wool price).

3 Result

3.1 Economic losses

All epidemiological parameters are presented in additional files. For the 2011-2014 period, the estimated mean for annual total economic losses caused by CE ranged from 70 to 74 million USD (73 million USD per year on average) (Figure 4; Table 4). The mean of maximal total range (min-max) obtained through Monte Carlo simulations went from 54 to 92 million USD per year. The average loss represented between 0.07% and 0.06% of Morocco annual Gross Domestic Product (GDP) (Table 4). Mean annual economic losses linked to human CE ranged from 16 to 18 million USD per year and that from animal infection ranged from 53 to 56 million USD per year (Figure 5).

Most losses were caused by productivity reduction in undiagnosed people and by animal product losses (milk, wool, meat, and fertility) (Figure 6).

Table 4: Annual economic losses for the entire country caused by CE and percentage of lost GNI and GDP

Year	Morocco GNI (million USD)	Total losses (USD)	% lost GNI	Morocco GDP (billion USD)	% lost GDP
2011	99,886.56	74,917,890.71	0.075%	101.370	0.073%
2012	100,417.88	72,367,275.25	0.072%	98.266	0.073%
2013	105,816.42	73,916,607.47	0.069%	106.826	0.069%
2014	106,120.31	70,806,534.55	0.066%	109.881	0.064%

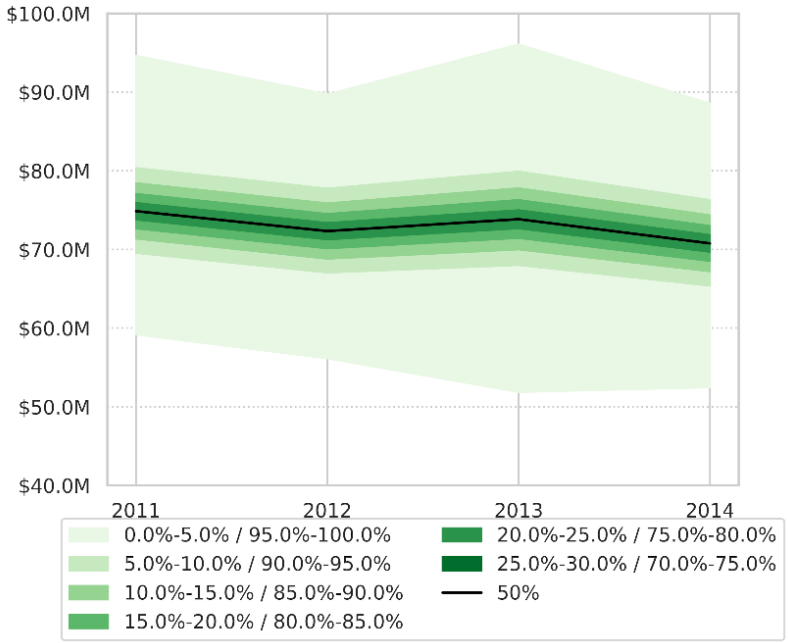

*Figure 4: **Total economic losses (whole country) caused by CE in humans and animals for the 2011-2014 period**. Monte Carlo simulations.*

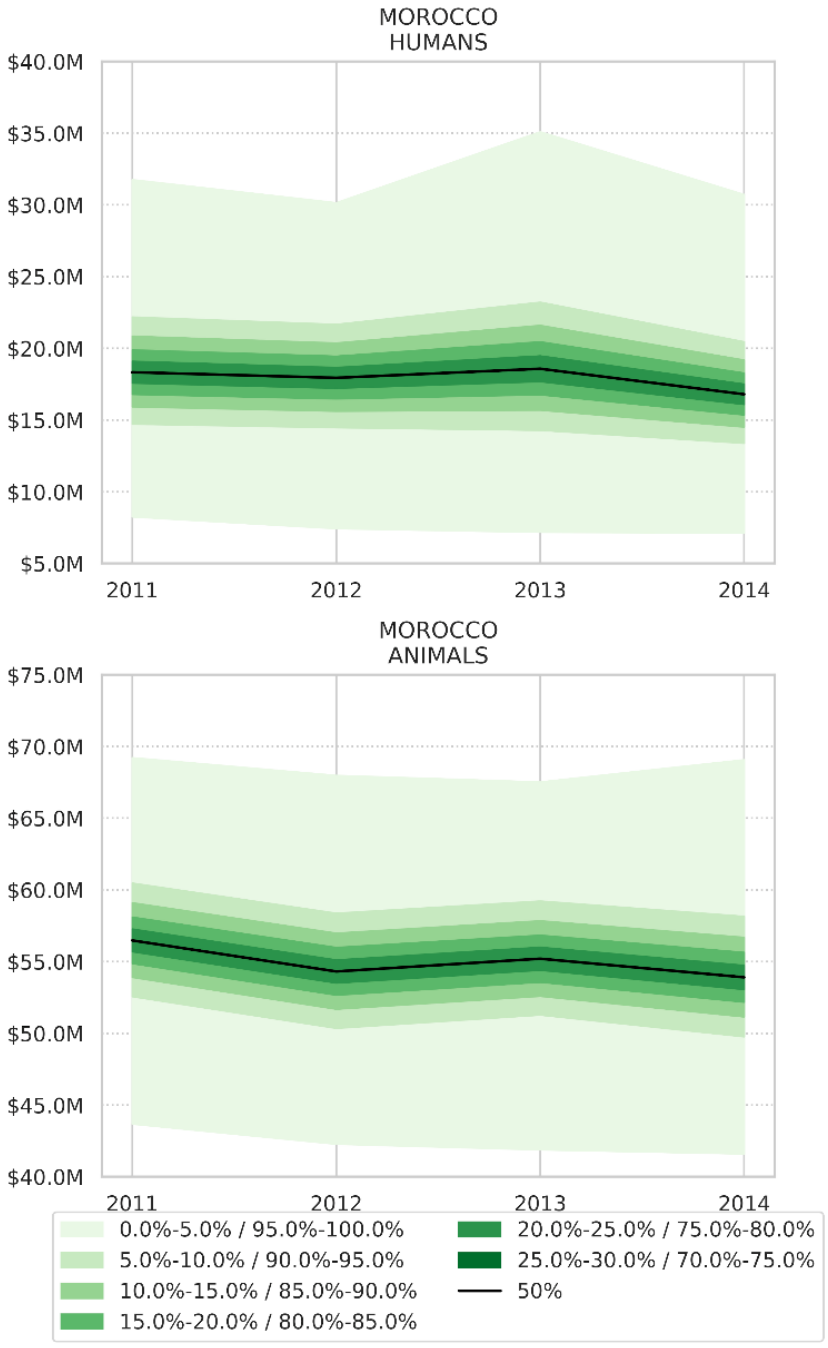

Figure 5: ***Economic losses (in million USD) for the whole country due to CE in humans (top) and livestock (bottom) for the 2011-2014 period.*** *Monte Carlo simulations.*

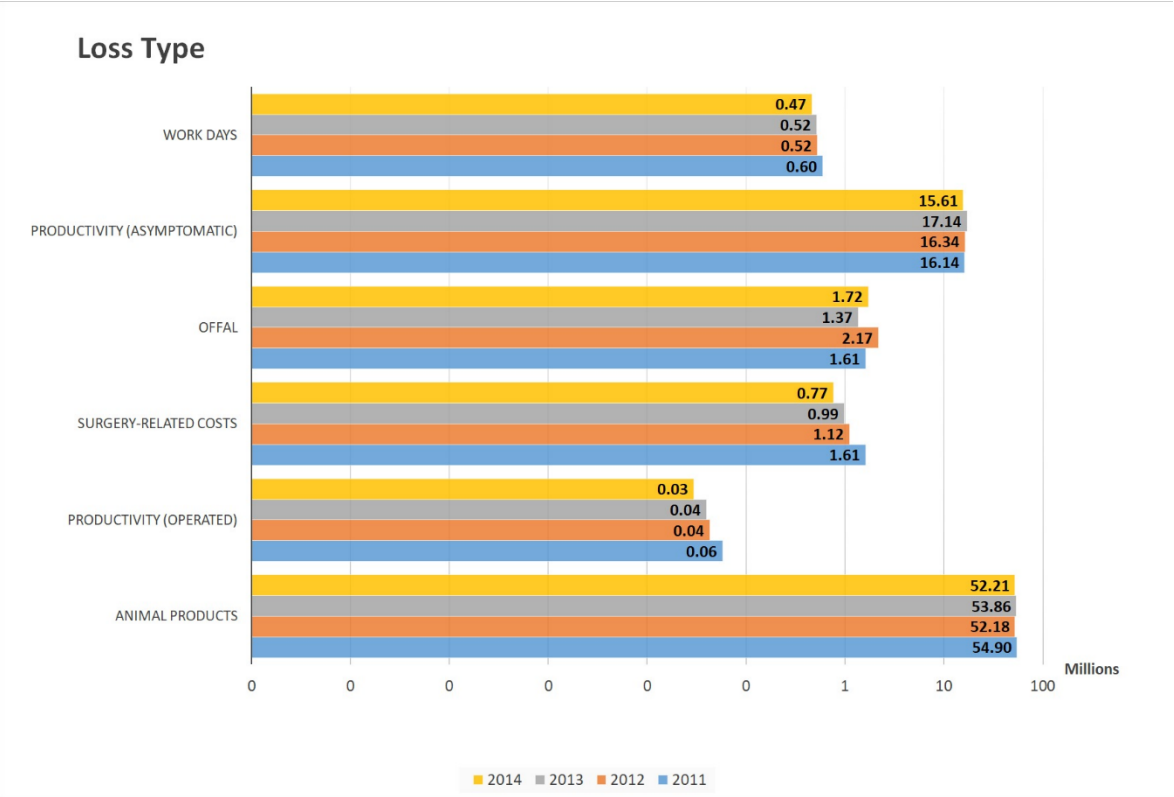

Figure 6: ***CE-linked economic losses according to the loss type (million USD) for the whole country, logarithmic scale****. Monte Carlo simulations. Losses related to surgery include medical and non-medical costs (transport, food, accompanying person…).*

In most Moroccan regions, losses varied from year to year, but no significant trend of loss reduction was observed in any region from 2011 to 2014 (Figure 7). Marrakech Tensift Al Haouz Tadla Azilal (MTATA) and Meknes Tafilalet (MT) were the regions with the highest economic losses. The province of Khénifra is part of the MT region. Laayoune Boujdour Sakia El Hamra Guelmim Essmara (LSBGE) has the lowest losses, but losses tended to increase from 2011 to 2014, especially losses caused by CE in animals (Figure 8).

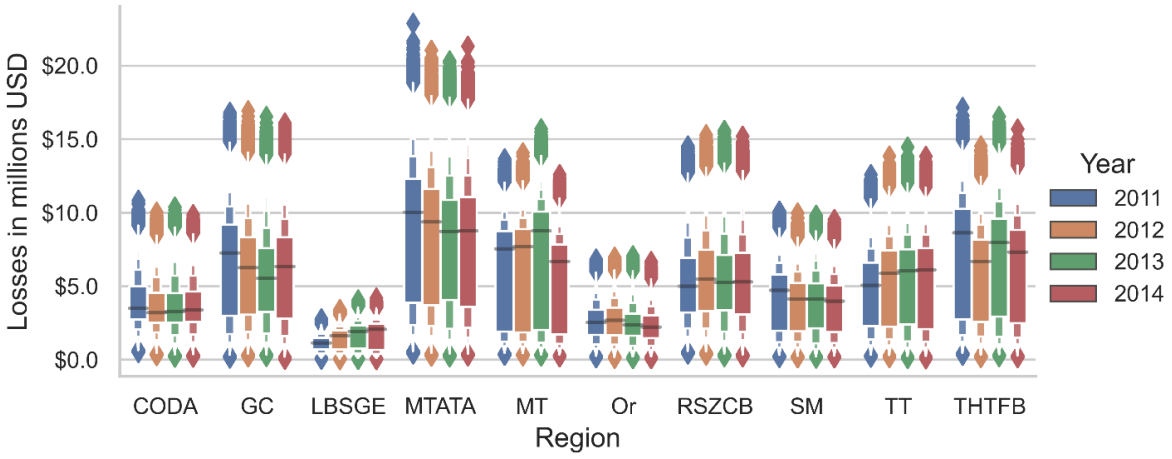

Figure 7: ***Economic losses (Y-axis=million USD) caused by CE by region estimated with Monte Carlo simulations.****.CODA: Chaouia Ouardigha Doukkala Abda; GC: Grand Casablanca; LBSGE: Laayoune Boujdour Sakia El Hamra Guelmim Essmara; MT: Meknes Tafilalet; MTATA: Marrakech Tensift Al Haouz Tadla Azilal; Or: Oriental; RSZCB: Rabat Sale Zemmour Zaer Chrarda Bni Hssen; SM: Souss Massa Draâ; THTFB: Taza Alhoceima Taounate Fes Boulemane; TT: Tanger Tetouan.*

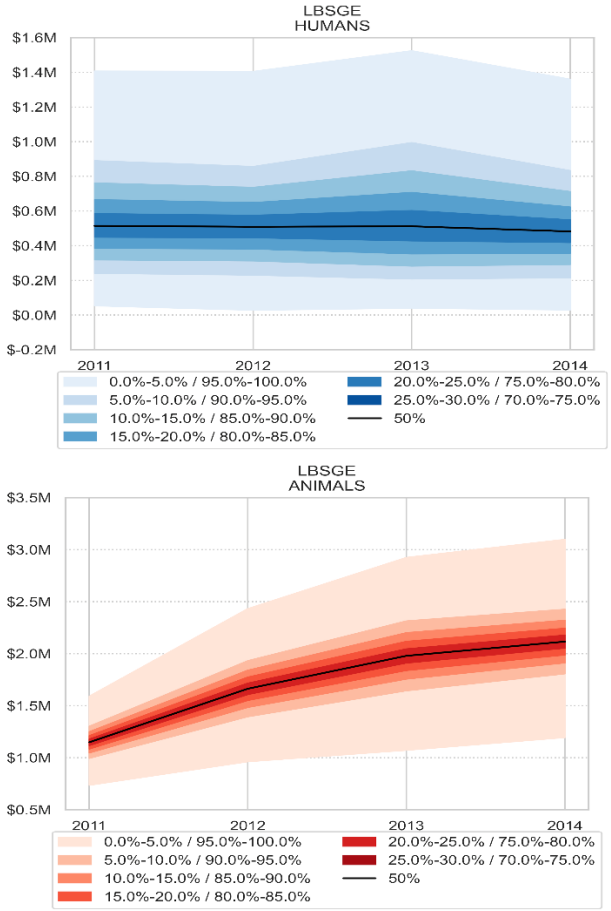

Figure 8: ***Economic losses (million USD) due to CE in humans (top) and animals (bottom) in the Laayoune Boujdour Sakia El Hamra Guelmim Essmara (LSBGE) region****. Monte Carlo simulation*

3.2 DALY and zDALY

The mean (min-max) estimated DALY per year at the national level was 160 years (106-238) (i.e. 0.5 years per 100,000 persons). The mean (min-max) estimated zDALY per year was 18,330 years (17,775-19,074) (i.e. 55 years per 100,000 persons). The DALY, which does not include productivity losses for asymptomatic human cases, represented approximately 0.87% of the total zDALY (Figure 9). ALE, which includes animal productivity losses, thus accounted for almost all of the estimated zDALY value.

The total annual economic losses converted in terms of lost years resulted in a mean (min-max) of 24,079 years (23,139-24,972) (i.e. 72 years/100,000 persons) (Figure 10).

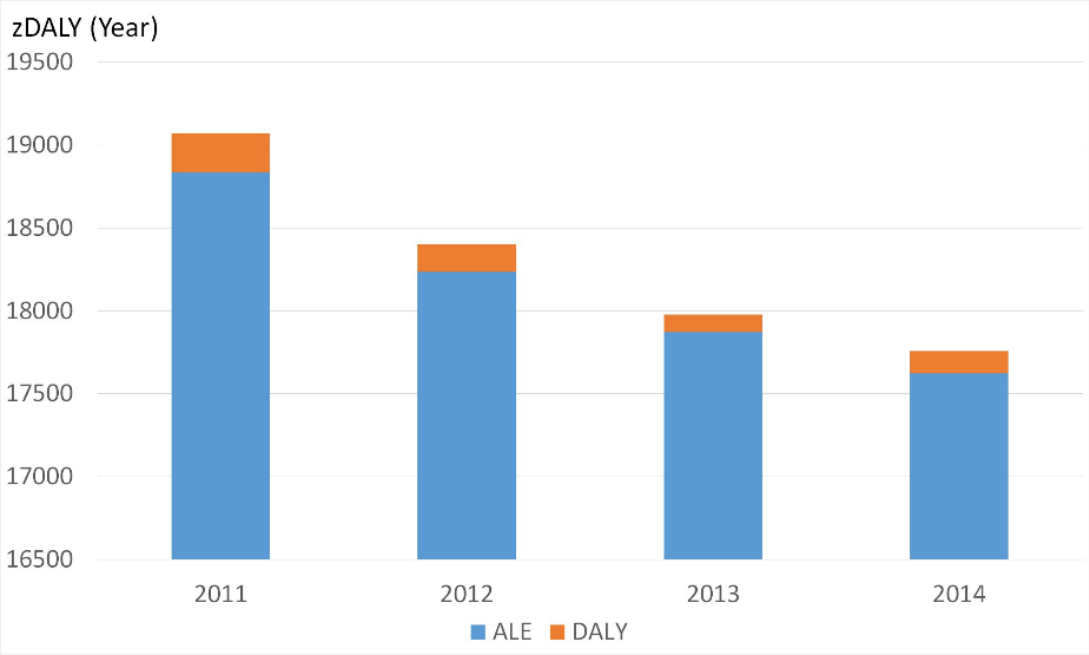

Figure 9: ***Estimated number of zDALYs per year due to CE in Morocco****. The zDALY was calculated by adding the animal loss equivalents (ALE in blue) to the disability-adjusted life years (DALY in orange) value.*

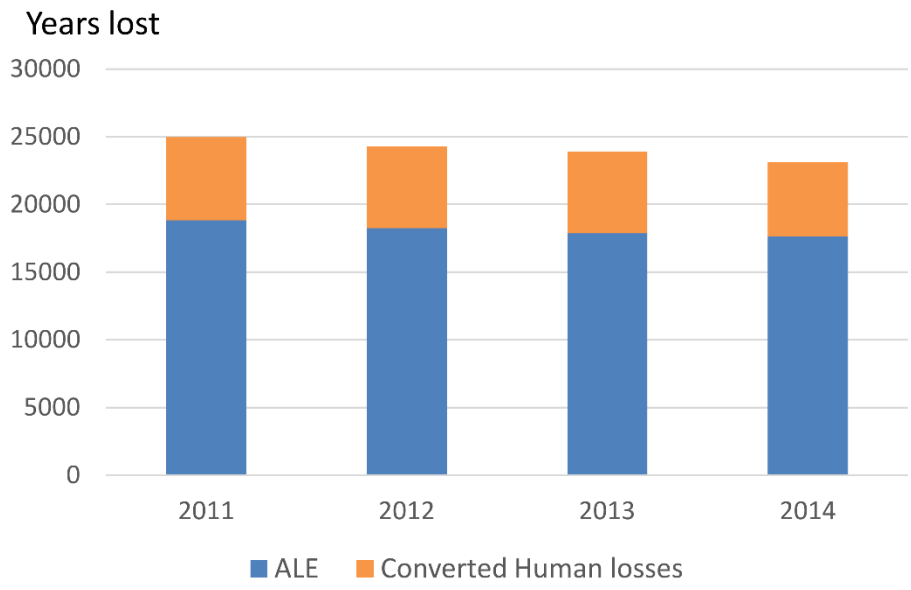

Figure10: ***Animal loss equivalents (ALE) and human losses converted to lost years of work.***

4 Discussion

This study carried out for the first time an estimation of CE impact on humans and livestock at the national and regional level in Morocco. To better understand CE effects, it is important to estimate its economic impact and the different items that contribute to its burden (Benner *et al.*, 2010). However, the accurate assessment is complex, even when estimations are limited to economic and monetary losses (Torgerson, Carmona and Bonifacino, 2000).

The results of this study indicated that CE caused huge economic losses in Morocco. Specifically, the estimated economic losses (73 million USD per year on average) represented 0.07% of Morocco GDP. Economic losses did not decrease from 2011 to 2014. Similar studies carried out in other countries reported variable economic losses: 14.7 million USD in Tunisia (0.03% of GDP), 200 million USD in Spain (0.01% of GDP), and 89 million USD in Turkey (0.01% of GDP) (Fasihi Harandi, Budke and Rostami, 2012). Thus, the results for Morocco indicate a higher loss in terms of GDP. Indeed, comparison of total losses among countries is not relevant due to the direct link between GDP and several parameters used for estimations (GNI per capita, value of production), as well as because of contextual and methodological differences. Only comparisons of relative values are therefore relevant (though still affected by possible methodological differences and availability of data), indicating here the particularly high burden caused by CE in Morocco.

Losses of human and animal productivity represented the most important part of CE economic burden in Morocco. This means that most of the huge impact goes unnoticed, explaining its actual neglect. Our study brings information on these unnoticed impacts that may help decision-makers and stimulate efforts towards CE control. Indeed, the major role of human productivity losses in the total economic losses indicates that CE neglect might hamper human development and social justice; because it mainly affects rural populations where physical effort is essential for ensuring livelihood and welfare. Productivity is one of the main drivers of economic growth, and productivity losses can have a significant impact on income (Creel and Ragot, 2015). Productivity losses caused by CE also increase the cost of living of the affected families (Fasihi Harandi, Budke and Rostami, 2012). CE-related animal productivity losses explained most of the monetary losses linked to CE in animals in our study. Similar results were found in other countries (Sariözkan and Yalçin, 2009; Benner *et al.*, 2010; Moro *et al.*, 2011; Fasihi Harandi, Budke and Rostami, 2012). Such losses reflect CE economic impact that is often not known by agricultural managers (Fasihi Harandi, Budke and Rostami, 2012). The present study, by including human productivity losses in the calculation of the monetary impacts, highlights how CE effects on human and animal productivity have a tremendous impact on rural livelihood and strengthen the need of action by policy makers.

Despite the national control programme launched in 2005, CE-linked economic losses did not significantly decrease in any region. Importantly, in the LBSGE region, where the human incidence of CE is lowest in the country, losses tended to increase during the 2011-2014 period. This could be explained by the poor implementation of the CE control programme in this region. In the MT region that includes also Khénifra, recent studies indeed indicate high CE prevalence in human and animals, and a massive infestation of dogs (Chebli *et al.*, 2017; Amarir *et al.*, 2020). Therefore, an in-depth analysis of CE prevalence and how the control programme has been implemented is necessary to understand the absence of results. Moreover, to improve the CE national control programme, the economic, ecological, cultural and social specificities of each region must be taken into account.

This study also estimated the DALY and zDALY (i.e. the time lost due to human and animal morbidity and mortality). Quality-adjusted life year (QALY) is another health-adjusted life year metric that could have been used for such estimations. Here, we chose the DALY because it is the

most common metric to quantify disease burdens in the Global South. Moreover, it presents the advantage that the addition of livestock losses (ALE) has been proposed to quantify the disease burden in animals in terms of zDALY (Torgerson *et al.*, 2018). The zDALY estimations for CE in other countries were 29.8 years per 100,000 persons per year in Tunisia, 27.2 years per 100,000 persons per year in Iran and 2.86 years per 100,000 persons per year in Spain (Torgerson *et al.*, 2018). Our analysis showed that in Morocco the zDALY was 55 years per 100,000 persons per year, a value nearly double to that found in Tunisia and Iran. Besides infestation rate, this may be explained by differences in livestock size and GNI per capita. Moreover, for our estimation, we did not rely only on CE prevalence at abattoirs, and we estimated a higher prevalence in adult animals, which contributes to the importance of the losses linked to animal production. Estimates of economic losses caused by CE in Iran and Tunisia were based only on CE prevalence at slaughterhouses (Majorowski *et al.*, 2005; Fasihi Harandi, Budke and Rostami, 2012). By applying the same conversion as for ALE to total monetary losses, we expressed in a DALY-like metric the importance of asymptomatic human cases through the loss of productivity, which, as highlighted here above, entails direct consequences in terms of quality of life. These results may directly influence the degree of priority ascribed to a disease by policy makers or the extent to which decision-makers from different sectors may feel concerned or not by the problem.

The multiplicity of components of the present estimation impose important limitations. Indeed, several parameters were subject to uncertainty that we tried to take into account by using Monte Carlo iterations to give a more nuanced image of the calculated impact. Similarly, losses from decreased fertility in camels were not included, due to lack of data. Obviously, the lack of data is linked to the poor surveillance, which in turn may be ascribed to limited awareness of CE importance. Unfortunately, this lack of data further compromises the accurate estimation of CE burden that would be needed to raise an awareness.

Such estimations aiming to fuel public decision-making, the issue of accuracy of estimations may also entail ethical concerns. Indeed, by taking into account different parameters, such as age, gender, environment, and patient employment status, we aimed to produce estimates that are as close as possible to the actual losses. One might observe, however, that the refinements in calculation in human health costs would make poor sense in terms of decision-making, since those refinements appear to affect only slightly the spectrum of values obtained through the Monte Carlo

iterations (having highlighted here above the many uncertainties in the parameter estimations). Furthermore, we can point to an ethical issue in the consideration of different values for the illness or death of different citizens of a country according to their gender or employment status. Scaled up at the international level, this issue may be raised in the same way if losses of different countries are to sum. If GNI of each country is used for estimations, human lives across the globe would indeed have various values, to the detriment of the weight of diseases affecting mainly poor countries. Hence, the quest for economic accuracy would deserve some close scrutiny for its practical meaning and ethical value when it comes to valuing health and human life.

Notwithstanding these various considerations, this first estimation, while taking account of the uncertainty around parameters, clearly demonstrates the economic importance of CE nationwide and should encourage efforts in the control and surveillance of the disease in Morocco.

Conclusion

Using an approach that combines financial and non-financial methods, this study estimated the economic losses caused by CE in humans and livestock in Morocco (nationwide and in the different regions) during the 2011-2014 period. The study showed significant losses in all regions, thus highlighting the poor implementation or lack of effects of the national CE control programme launched in 2005. The losses were mostly unnoticed (i.e. human and animal productivity losses), and this could partly explain why this zoonosis is neglected in Morocco. This study should encourage decision-makers to invest more in CE control and surveillance. Additional studies are now needed to understand the failure of the CE control programme, by analysing the stakeholders' involvement and the sociological determinants of CE and its control in the various regions of Morocco.

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Supporting information (Annexes Section)

- **Table S1**: Parameters used to estimate animal organ losses at slaughterhouses
- **Table S2**: Costs of CE in patients who underwent surgery
- **Table S3**: Population of Morocco according to the 2014 census (HCP)

- **Table S4**: CE incidence (i.e., individuals undergoing surgery for CE at a public-sector hospital) in the different regions of Morocco
- **Table S5**: Parameters used to estimate livestock production losses
- **Table S6**: Age at disease onset (a) and length of hospital stay (data for Khénifra provincial hospital)
- **Table S7**: Price of different animal products (in Moroccan Dirhams, Dh)
- **Table S8**: Number of ewes and does (those are the words used to define adult females of these two species) per region and per year (per 1000 heads)
- **Table S9**: Number of cows by region and by year (per 1000 heads)

Chapitre 2

Programme national de lutte contre l'hydatidose au Maroc: Enjeux & Pistes de réflexion

Article en cours de correction suite au processus de révision dans un journal à comité de lecture

Préambule

Le programme national de lutte contre l'hydatidose (PNLH), lancé officiellement depuis 2007, propose une série de mesures de lutte destinées aux ministères chargés de ce programme : Ministère de la Santé, Ministère de l'Agriculture et Ministère de l'Intérieur. Le but de cette deuxième étude, est d'identifier les obstacles et les enjeux de l'applications de ces mesures de lutte dans plusieurs régions du pays. L'objectif est d'exploiter les points forts et les points faibles du PNLH. L'identification des obstacles peut, suivant le lieu où l'obstacle est situé, conduire à des réorganisations de l'approche de lutte d'une manière différente. Nous avons posé le choix pour cette étude d'ouvrir le cadre d'application au-delà de la seule hydatidose, nommément à la rage et à la tuberculose bovine, afin de mettre en évidence les défis communs que le contrôle de ces zoonoses présente.

Using qualitative approaches to explore challenges of integrated programs for zoonosis control in developing countries: example of hydatidosis control in Morocco

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Abstract

Cystic echinococcosis, rabies and bovine tuberculosis are major neglected zoonosis in many developing countries as they are in Morocco. The control of these zoonoses intersect in the management of slaughterhouses and/or in the control of dog population. Exploring the case of Morocco, this study proposes a qualitative approach to understand the causes leading to this defective management. In particular, the study aims at going beyond the often-invoked "lack of means" in the explanation of failures in disease control in the Global South. A qualitative approach was carried out, during three years (from 2014 to 2016) in five regions of Morocco: Rabat-Sale-Kenitra, Mellal-Khenifra, Sous-Masaa, Laayoune-Sakia El Hamra, and Guelmim-Oued Noun. Participant observations and 81 interviews were carried out with agents responsible of the services managing slaughterhouses and dog population control, as well as slaughterers. The recordings were subject to full transcription and narratives were analyzed with R software using the RQDA package. Triangulations and criteria proposed by Guba and Lincon were used to assess the validity of the approach. This study revealed many factors other than financial problems, which are the overlapping of powers, conflicts of interest and professional practices. The control of zoonosis requires the commitment of all structures, the establishment of a national and inter-regional strategy and the updating of the legislative arsenal.

Keywords: Qualitative approach; Integrated control program of zoonosis; Morocco; Slaughterhouses; Dog population control.

1 Introduction

Cystic echinococcosis, rabies and bovine tuberculosis are major neglected zoonoses, which particularly affect developing countries, especially rural and poor areas. Cystic echinococcosis (CE) affects over a million person and it is responsible for losses over US $ 3 billion per year (Brunetti and Mccloskey, 2016). Canids (especially dogs) are the definitive hosts of its causative parasitic agent. They are contaminated by ingestion of contaminated viscera from intermediate hosts (ruminants) (Thompson and McManus, 2002). Humans is infected by CE by ingesting contaminated food or water, which makes this parasite a public health problem (Toma *et al.*, 1991). Rabies is a viral disease, fatal in all cases, and domestic dogs are the main responsible species for rabies virus transmission to humans (WHO, 2020b). Around 60 thousand people die from rabies each year (one person every nine minutes) (WHO-FAO-OIE, 2018). The average cost of post-exposure rabies prophylaxis has been estimated at an average of US $ 108 (WHO-FAO-OIE, 2018). Tuberculosis is an infectious disease, which affects 10 million people every year and kills 1.5 million people every year, making it the world's leading infectious disease (WHO, 2020c). In humans, infection is primarily caused by *Mycobacterium tuberculosis*, but the animal pathogen, *M. bovis*, was possibly the most important zoonotic agent in human history (Abalos and Retamal, 2004). Nowadays, transmission of bovine tuberculosis to human still occurs through consumption of contaminated meat or raw milk and contributes to the overall burden of tuberculosis (Farougou, AM and APLOGAN, 2011).

Morocco, like other developing countries, is endemic to these three zoonoses, despite the national control programs of cystic echinococcosis, rabies and tuberculosis (Comité interministériel de lutte contre L'Hydatidose, 2007; Direction de l'Epidémiologie et de Lutte contre les Maladies, 2018; Ministrére de la santé, 2018). Twenty cases of human rabies are recorded per year (Direction de l'Epidémiologie et de Lutte contre les Maladies, 2018), the incidence of tuberculosis is 103 cases per 100,000 inhabitants (Ministrére de la santé, 2018) and the average annual incidence of cases operated for hydatid cysts is 2.2 per 100,000 (Saadi *et al.*, 2020). The control programs of these three zoonoses intersect in the control of meat at the slaughterhouse level and/or in the control of the dog population (figure 1). The present failure of these three control programs in Morrocco may also intersect at these same levels. Indeed, it has been reported that the defective state of slaughterhouses and/or the high number of dogs are the major causes of the persistence of these zoonoses in Morocco and other developing countries (Aoun *et al.*, 2009; Ikhlass El Berbri *et al.*,

2015; Tebug *et al.*, 2015; Thys *et al.*, 2019). In-depth analysis is requested to go beyond the often-invoked assertion of “lack of means” as an explanation to disease control failures, with a special focus in the present case on slaughterhouses and dog population management. This study proposes a qualitative approach to the question, this mode of research being identified as suitable for the open exploration of question in the form of "how" and "why" (Dumez, 2012).

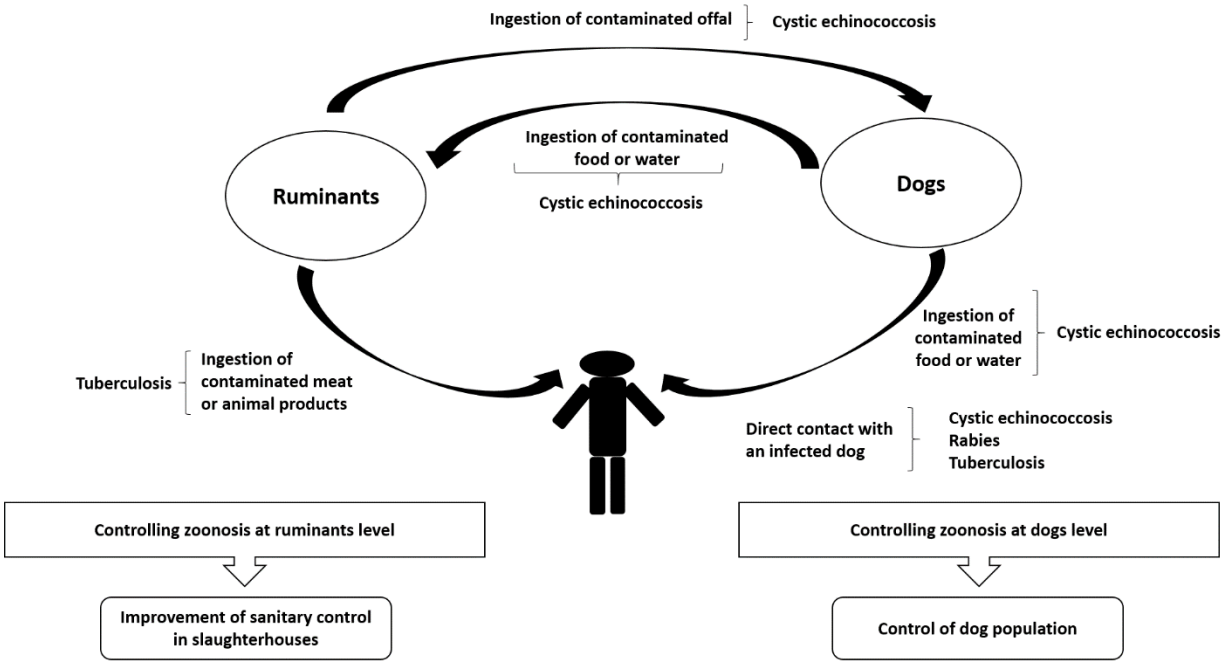

Figure 1: ***The life cycle of cystic echinococcosis, rabies and bovine tuberculosis: intersection of control measures***

2 Materials and methods

2.1 Ethics approval and consent to participate

Close attention was paid in respecting ethical considerations following the instructions of Guidelines for Research Ethics in the Social Sciences, Humanities, Law and Theology (Norwegian National Research Ethics Committees, 2016). A formal interview setting the right to informed consent was strictly observed: verbal consent was sought from the respondents giving them as much information about the purpose of the interview, the estimated time required, and the outcome of the study. Measures to safeguard the anonymity and confidentiality of the respondents were observed at all times during the fieldwork and data analysis process. This work was authorized by

Department of Pathology and Veterinary Public Health committee, Agronomic and Veterinary Institute Hassan II, in Rabat, Morocco.

2.2 Study areas

The study was undertaken from 2014 to 2016. The regions were identified based on the epidemiological situation of cystic echinococcosis (CE), which combines the two control points under scrutiny, i.e. slaughterhouses and dog populations. Thus, five regions were chosen according to their geographical locations, the incidence of the CE and the representation of socio-economic differences: Rabat-Salé-Kénitra (Rabat, Bel Ksiri and Oulmes); Béni Mellal-Khénifra (Khénifra); Sous-Masaa (Agadir); Laâyoune-Sakia El Hamra (Laayoun); and Guelmim-Oued Noun (Guelmim) (Figure 2). Rabat-Salé-Kénitra is the administrative capital, located in the north of the country. Khenifra is the capital of the Middle Atlas, where the incidence of CE surgery in human is among the highest in Morocco. Agadir, located in southwestern Morocco, where the incidence of the disease in humans is high. Guelmim-Oued Noun, located in southern Morocco, is the least affected region of the country.

Figure 2: The five study regions in Morocco. Adapted from Wikimedia commons: https://commons.wikimedia.org/wiki/File:Morocco_Regions_2015_numbered.svg

2.3 Study design

The first step consisted of visits to all slaughterhouses in the studied regions. In each region, we stayed between 1 to 30 days in the slaughterhouses, to observe its infrastructures, the work processes and to get acquainted with all the people who work there (employee, veterinary services, slaughterers, guards ...).

The second step aimed to identify the different structures responsible for the management of slaughterhouses and dog population. The Ministry of Agriculture, presented by National Office of Food Safety (ONSSA), manages the epidemiological surveillance at a slaughterhouse and the management of contaminated offal. The local authorities (through the municipal hygiene offices) represent the Ministry of the Interior. They are in charge of controlling the dog population and the management of the slaughterhouse. In addition, slaughterers manage the slaughter process. Afterwards, a series of in-depth individual interviews (IDII) were conducted with the identified structures. The list of recruits included slaughterers (n=34), official from local authorities (n=26), officials of municipal hygiene offices (BMH) (n=5) and the veterinary services from the National Office of Food Safety (ONSSA) (n=16). Totally, 81 in-depth individual interviews were conducted (Table 1). Interviews were conducted until the data saturation. Saturation is reached when the data collected has sufficient information and the capacity to obtain new additional information was reached (Fusch and Ness, 2015a).

Table 1: In-depth individual interviews carried out. ONSSA: National Office for Sanitary Safety of Food Products; BMH: Municipal hygiene office.

Region	Category	Structure	Number of interviews	Period
Bel Ksiri	Slaughterers	Slaughterhouses	5	2014
	Official	Local authorities	4	2014
	Veterinary	ONSSA	1	2014
	Veterinary	BMH	1	2014
Guelmim	Veterinary	ONSSA	1	2015
	Official	Local authorities	3	2015
	Slaughterers	Slaughterhouses	4	2015
Laayoune	Veterinary	ONSSA	2	2015
	Official	Local authorities	5	2015
	Slaughterers	Slaughterhouses	6	2015
Agadir	Official	Local authorities	5	2016
	Veterinary	ONSSA	4	2016
	Slaughterers	Slaughterhouses	4	2016
	Official	BMH	2	2016
Khenifra	Veterinary	ONSSA	3	2016
	Officials	Local authorities	6	2016
	Slaughterers	Slaughterhouses	4	2016
	Official	BMH	1	2016
Oulmes	Official	Local authorities	2	2016
	Veterinary	ONSSA	1	2016
	Slaughterers	Slaughterhouses	6	2016
Rabat	Veterinary	ONSSA	4	2016
	Slaughterers	Slaughterhouses	5	2016
	Official	Local authorities	1	2016
	Official	BMH	1	2016
Total			**81**	

2.4 Data collection

An interview guide was developed to facilitate the discussions. The purpose of the interviews was to identify the slaughterhouse management, seizure management, as well as the modalities and difficulties of setting up the control of dogs. A thematic analysis was carried out around the following items: development of slaughterhouses, management of seizures, and control of the dog population. The interview guide was tested in another province (Sidi Kacem) in Nouirate, with a veterinarian. The aim was to determine whether the participants understood all the questions and whether the duration of the discussion was appropriate (Schmeer, 2000). To facilitate the

discussions, a moderator (SA) facilitated the discussion and a reporter took notes. All interviews were conducted face-to-face in a quiet room. The interviews were recorded by an audio recorder and a video camera. Interviews were conducted in Arabic. The duration of the discussions varied from 20 to 45 minutes.

2.5 Data analysis

Recordings and observation notes were transferred to a computer and shared with the team. They were transcribed and translated from Arabic into French (the common language of the team). Notes and transcripts were anonymous and verified by the moderator (SA) and reporter. To improve reliability, a third team researcher (SH) reviewed the transcripts. The transcripts were entered on software R. The RQDA package was then mobilized to analyze the data. Provisional codes (themes) were developed: strengths and weaknesses of dog population and health control in slaughterhouses. Collaboration between different structures were added as emerging themes during the analysis process. The results were then compared between the different participants and between the different study sites.

2.6 Validation process

A widespread criticism of qualitative approach pertains to the validation of data. Unlike quantitative research, it is difficult to prove the accuracy or falsity of an observation. The validation of qualitative methods is the ability to produce results that can significantly contribute to a better understanding of the studied phenomenon. Validity in qualitative research is defined as the degree to which the results are interpreted correctly (Boudreault and Arseneault, 1994). Triangulation is a criterion of internal validity (Guba, 1981). Triangulation involves implementing multiple sources of approaches and / or data, which contributes to improving the reliability of results and achieving data saturation (Stavros and Westberg, 2009). In this study, the data was obtained from observations and interviews (data triangulation), and three researchers performed the data analysis (researchers' triangulation). Parallel to the validity criteria in qualitative research, Guba and Lincoln proposed four alternative criteria for judging qualitative research: credibility (internal validity), transferability (external validity), dependability (reliability) and confirmability (objectivity) (Lincoln and Guba, 1985). The results of this study present only the point of view of the participants in this study, which ensures its credibility. Transferability is ensured when the results of qualitative research can be generalized or transferred to other contexts (Proulx, 2019). The

entire study process was well explained, from the development of research questions and data collection, to neutral analysis and interpretation, which allows its transferability to other subjects or other context. Dependability is the ability to replicate a study (Lincoln and Guba, 1985). The analysis of this data was carried out by coding and classifying the data into categories and subcategories. Confirmability refers to the transparency of the researcher concerning his positioning. Confirmability is referred when other researchers confirm the results. Throughout this study, data was verified by two researchers, and rechecked by a third researcher. Figure 4 present the different scientific criteria followed in this qualitative research.

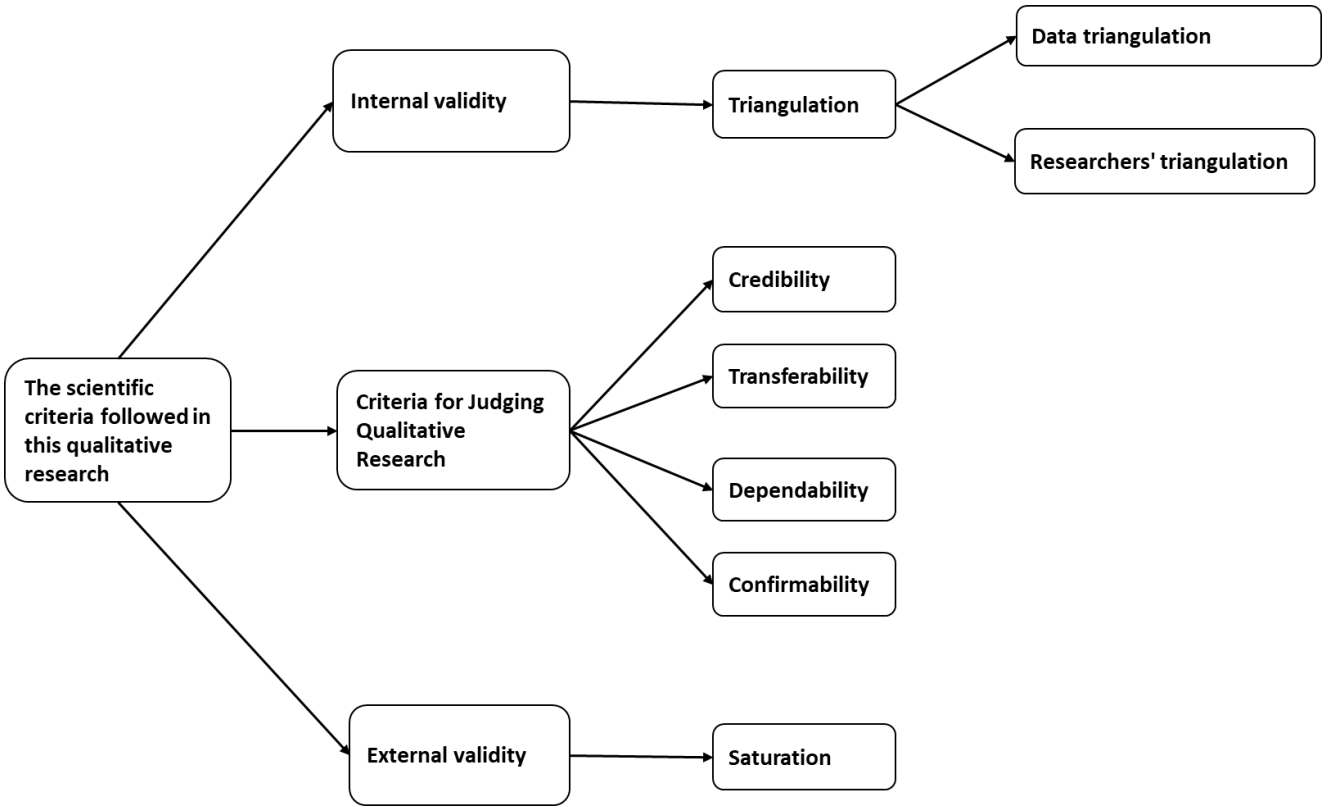

Figure 4: ***The scientific criteria followed in this qualitative research***

3 Results

3.1 Development of slaughterhouses

Veterinarians and BMH officials reported that the re-development of slaughterhouses is the key to the fight against many zoonosis. They added that the development of slaughterhouses is important, but far from being realized given the current situation of the Moroccan slaughterhouses, and only few slaughterhouses in the country respecting hygiene standards. The representatives of the

municipalities revealed that the development of slaughterhouses requires a large budget. They explained that 40% of the slaughterhouses' income goes to orphanages (their only source of income) and 3% for ONSSA veterinary services.

> *"Large part of the slaughterhouse income goes to orphanage accounts; there isn't much money to improve the slaughterhouse" (Local Authority / Khenifra)*

The ONSSA veterinary services declared a lack of means to denature and destroy the seized organs. The municipalities mentioned that they provide the equipment that is in their possession and veterinarians must adapt to the lack of means. The veterinary services revealed that there is an overlap of responsibility between ONSSA and the municipalities.

> *"We have a lack of destruction products. The destruction of the seizures is our responsibility, but the supply of the means of destruction is under the responsibility of the municipality, we are always in conflict" (Veterinarian / Guelmim)*

The veterinary services have also declared that they are in permanent conflict with the owners of the animals slaughtered because of seizures. They said that these conflicts can become a threat during seizures of an entire carcass, and that even some vets have been transferred after seizures of carcasses of calves infected by tuberculosis.

> *"We cannot work properly with slaughterers, they do not accept seizures, and it can become a threat if we seize a whole carcass" (slaughterhouse technician/ Bel Ksiri).*

> *"One of our comrade was transferred from this slaughterhouse after seizing a carcass of a calf suffering from tuberculosis, and this happens everywhere in Morocco" (veterinary services/ Guelmim)*

When we visited the slaughterhouse of Laâyoune, during the veterinary control, soldiers were ensuring the security of the slaughterhouse to avoid any conflicts and strengthen the sanitary control, after a series of conflicts in the past. In some regions visited, veterinarians delegate the sanitary control of meat to ONSSA technicians, because, sometimes one veterinarian is responsible for several slaughterhouses, geographically dispersed.

Slaughterers were aware of the danger motivating the seizure of carcasses. However, they explained that they refuse to see their carcasses seized because of the loss of money. They explained

that normally, after the seizure of a whole carcass, they are reimbursed by the state but at a rate far below the value of the carcasses. They added that the repayment takes several months.

The value of the carcasses seized is three or four times higher than reimbursements. In addition, you have to wait months and months to be reimbursed!!! How can we live then if they seize our carcasses? (Slaughterers/Khenifra)

The veterinary services declared that for certain zoonosis (such as cysticercosis), in order for the carcasses to be consumable, they must go through a refrigerated room. However, the majority of slaughterhouses do not have the needed equipment. During visits to slaughterhouses, some of these slaughterhouses were in fact equipped with refrigerated rooms. However, most were not active, being used for storage of equipment or as changing rooms.

We also noticed a large number of dogs around the slaughterhouses. When we asked the question why they do not prevent the access of dogs to the slaughterhouses, the answer was always the absence of walls and closures to protect the slaughterhouses. Among the slaughterhouses visited, several had a wall to prevent any access of dogs. However, we noticed that the doors were open, and dogs were inside. In addition, these dogs seemed to be familiar with people at the slaughterhouses, since they did not flee when people approached, and these dogs were only chased away after our arrival.

3.2 Dog population control

Veterinarians and local authorities reported the lack of a national strategy to control the dog populations. In addition, the officials of the communes revealed that the control of the canine population is done by firearm (like Belksiri and Rabat), and in other regions by the strychnine (Laâyoune, Guelmim and Tan-Tan). However, animal protection associations and civil society express their refusal of this practice, especially since they are semi-stray dogs (owned dogs).

"When we lead the slaughtering campaigns of stray dogs, the associations criticize us, but we cannot do otherwise, we do not have kennels" (Local Authority / Rabat)

Municipal officials said the dog slaughter campaigns are conducted when the local population declared their dissatisfaction with the high number of dogs in their area. The municipality did not have a specialized team.

In the southern region (Sahara), stray dogs have a different profile compared to the rest of the country. The veterinarians claimed that there are stray dogs returning to their wild state. They explained that this phenomenon is caused by some people who come leaving in the Sahara for a limited period, and when they leave, they abandon their dogs, thus creating a population of wild dogs, which attack the livestock and human.

"We are facing a serious problem, the wild dogs! People when they quit here, they abandon their dogs, and these dogs prey on the chameleons, and sometimes people"
(Veterinarian/ Laayoune)

4 Discussion

In Morocco, cystic echinococcosis, rabies and bovine tuberculosis are public health problems, despite the control program of these zoonoses. The common point between these three zoonosis are slaughterhouses and/or dog population control. Adopting a qualitative research method, we collected the perceptions of the structures responsible for the management of slaughterhouses and dog population. The information gathered highlighted some of the obstacles encountered at slaughterhouses and during dog management.

The management of slaughterhouses and dog population were revealed as a major problem in the fight against zoonosis in Morocco (Ikhlass El Berbri *et al.*, 2015; Bardosh *et al.*, 2016). While the "lack of means" indeed appears as a first-presented answer, in the present study refining this rationale often leads to more accurate observations. Hence, in slaughterhouses, the financial management maybe pointed out, with almost half of the slaughterhouse incomes going to orphanages while needs of investment are obvious. The municipalities directly ensure the management of the slaughterhouse budget, which constitutes a major debate with veterinary services of ONSSA. This budget management issue may thus refer in this case to a question of priorities of the managing stakeholder and weak position in this regard of stakeholders showing a higher interest in veterinary public health matters. The income from slaughterhouses represents the only financial source of orphanages. Therefore, the municipalities are faced with a dilemma between the hygiene of slaughterhouses which affects public health and a social problem, which would call them to consider politically sensitive taxes on other economic activities. The study also revealed that the lack of equipment may in fact include a lack of rigor in using the available equipment, particularly concerning refrigerated rooms and protecting fences.

Crossing the question of budget management, this study pinpoints an overlap of responsibility between ONSSA and the municipalities. The management of the slaughterhouse and the destruction / denaturing products are the responsibility of the municipalities, while health control is the responsibility of ONSSA (Comité interministériel de lutte contre l'Hydatidose /Echinococcose, 2007). This can create tensions, especially in the absence of a legislative arsenal, while intersectoral collaboration can reinforce the knowledge or material gaps of each institution (Marcotty *et al.*, 2013). For example, in the fight against AIDS in Cameroon, the overlapping responsibilities created a competition between institutions (Tantchou Yakam JC, 2008). Conflicts also exist between the veterinary services and the slaughterers, conflicts that can turn into threats. Insecurity of veterinary services is a big obstacle to the strengthening of sanitary control in Morocco and other developing countries. This study revealed the origin of these conflicts, which cause insecurity: the partial and delayed reimbursement of seized carcasses (if any). The Moroccan law requires "full or partial" reimbursement (Le ministre de l'agriculture du développement rural et des eaux et forets, 2001). However, these refunds were deemed here inappropriate by recipients because they do not present the value of the products in the market. As long as this problem exists, either in Morocco or in other countries, the safety of veterinarians is endangered, which will directly affect health control at slaughterhouses.

To control the canine population, the municipalities are eliminating dogs by gunshot or strychnine poisoning, with no general strategy at the national or inter-regional level. Killing dogs has proven ineffective in the long term, because new dogs from other neighboring communities replace killed ones (Smith *et al.*, 2019). Management of the dog population which respects animal welfare is not incompatible with the effectiveness of the protection of human health (RAPAD Maroc, 2016). For example, cystic echinococcosis control programs in Argentina, Chile, and Uruguay have been successful without compromising animal welfare, relying on treating dogs with PRAZIQUANTEL (Moro and Schantz, 2007). In addition, the vaccination of dogs against rabies has allowed its control in South America (LarghiJ *et al.*, 1988). A rabies control strategy, based on the sterilization and vaccination of dogs in Jaipur in India, respecting the well-being of dogs, resulting that the number of human rabies cases had fallen to zero in the program area (Reece and Chawla, 2006).

Planning a dog control campaign involves collecting and analyzing epidemiological data, involving the local population and training a specialized team (Carter, 2008). In the present case, the

campaigns were mentioned as being initiated upon request of citizens and being conducted by unqualified personnel. Dogs in Morocco have the status of "semi-stray dog" which have most often an owner (Ikhlass El Berbri *et al.*, 2015; Thys *et al.*, 2019). However, a new phenomenon begins to gain momentum in the Sahara: wild dogs. In addition to the risk of zoonotic transmission, wild dogs attack native animals, livestock, and the population but could also entail wider ecological consequences (Moutou, 1993).

5 Conclusion

Following a qualitative approach, including interviews and on-site observation, allowed understanding the subtleties of the overall dysfunction of zoonotic control at the level of slaughterhouses and dog population control. The study revealed that in Morocco, financial problems are not the only origin of control failure, and that the latter rather pertain to issues in the coordination between stakeholders, lack of adoption or acceptability of a set of measures, and misalignment of stakeholder priorities with zoonotic control.

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Chapitre 3

Analyse des Parties Prenantes

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Préambule

La deuxième étude a mis en lumière certains obstacles à la lutte contre l'hydatidose/échinococcose au Maroc, à travers l'analyse qualitative des situations dans les abattoirs et la gestion des populations canines. Parmi ces obstacles, nous avons identifié un problème sous-jacent de coordination entre acteurs et de divergences des priorités individuelles et collectives. Cette troisième étude propose d'approfondir cette question à l'aide de la méthode dite « d'analyse des parties prenantes », généralement utilisée en management et en sciences politiques. Ce faisant, ce travail propose également une structure d'analyse qui fournit une application simplifiée de la méthode, que l'on gagnerait à appliquer de façon systématique à l'analyse d'une diversité de programmes de lutte contre des zoonoses.

Stakeholder analysis to improve the national control program of cystic echinococcosis in Morocco

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Abstract

Cystic echinococcosis (CE) is a major zoonosis in Morocco. Despite a national hydatidosis control programme (NHCP) established in 2005, CE burden is still high nationwide. The aim of this study was to carry out an NHCP stakeholders' analysis to identify weak points and propose improvement strategies. In total, 164 semi-structured interviews were carried out with national and local stakeholder representatives, and one stakeholders' workshop was organized. Classical categories of stakeholder analysis (i.e. involvement, interest, importance, influence, priority, and power) were semi-quantified. Based on these categories, an analytical framework was proposed, by selecting elements from the stakeholder analysis, to structure the assessment around three criteria: measure appropriation, political agency, and socio-technical agency. Besides specific weak points of the NHCP, the analysis highlighted the complexity of implementing a zoonotic disease control programme due to the involvement of many different stakeholders. Finally, this study provides a simplified stakeholder analysis method that could be used to assess other health programmes targeting zoonotic diseases, in Morocco and in similar countries

Keywords: Cystic echinococcosis; Morocco; National hydatidosis control programme; Stakeholder analysis.

1 Introduction

Cystic echinococcosis (CE) is a neglected zoonotic parasitic disease caused by the tapeworm *Echinococcus granulosus*. Dogs and wild canids harbour the adult parasite in their intestine (final hosts), while the larval form is found in tissues and viscera of various ungulates (intermediate hosts). Humans may be infected as an intermediate host and epidemiological dead-end (Thompson and McManus, 2002). CE is one of the most prevalent and costly parasitic diseases in the world (WHO/OIE, 2002). The annual costs associated with the treatment of human cases and with livestock losses caused by this zoonosis are estimated at US $ 3 billion (OMS, 2020).

In Morocco, CE is endemic (Chebli *et al.*, 2017). Its estimated prevalence in dogs ranges between 23.5% and 38.8% (owned dogs) and between 51.3% and 68.5% (stray dogs) (Amarir *et al.*, 2020), and in humans is approximately 1.9% (Chebli *et al.*, 2017). However, human CE incidence is underestimated in Morocco because only surgical cases are recorded, but many people with hydatid cysts are not treated by surgery, and therefore will not be reported (Mansouri *et al.*, 2015; Chebli *et al.*, 2017). In livestock, CE prevalence at slaughterhouses is 12.4% in cattle, 8.7% in camels, 8.4% in sheep, and 4.7% in goats (Saadi *et al.*, 2020). A national hydatidosis control programme (NHCP) was established in 2005 and officially launched in 2007. An inter-ministerial committee was created, gathering the Ministries of Health, of Agriculture, and of the Interior. It elaborated an information guide that provides the necessary epidemiological knowledge (Comité interministériel de lutte contre L'Hydatidose, 2007), and supervises and monitors the programme implementation at the national and regional levels. The NHCP is based on two main strategic axes: i) preventive measures, and ii) treatment of the human disease (Comité interministériel de lutte contre L'Hydatidose, 2007). Specifically, a set of preventive measures are focused on interrupting the parasite life cycle, protecting livestock, and controlling the dog population, particularly by improving slaughterhouse sanitary standards, controlling stray dogs, and deworming dogs. Activities related to this axis are organized and supervised by the Ministry of Agriculture and Ministry of the Interior. The CE epidemiological surveillance at slaughterhouse and infected offal disposal are managed by the Ministry of Agriculture through the National Office for Food Safety (ONSSA). The dog population and slaughterhouse controls are managed by the Ministry of the Interior via the local municipal hygiene offices. On the other hand, the epidemiological surveillance, detection and treatment of hydatid cysts in humans are organized by the Ministry of Health through the local health delegations and public hospitals. Raising awareness on CE

importance in the population is shared by the three Ministries. In addition, the Ministry of Education has been involved in the preparation of an awareness brochure for children, and the Ministry of Islamic Affairs carries out awareness campaigns in the mosques.

The NHCP aim was to halve the incidence of CE by 2015 (Azzouzi, 2009). However, the available data suggest that this objective has not been reached yet. Indeed, the yearly losses due to CE were estimated in Morocco at 73 million USD (54–92 million USD) for the 2011-2014 period (Saadi *et al.*, 2020). Moreover, a recent study to estimate the prevalence of human abdominal CE in the Mid-Atlas (hyper-endemic region) by ultrasonography showed an overall prevalence of 1.9% (Chebli *et al.*, 2017). Another study in the Sidi Kacem region estimated an overall infection prevalence of 42.9% in cattle, 11.0% in sheep, and 1.5% in goats (I El Berbri *et al.*, 2015). No formal evaluation of the NHCP has been done yet. However, such assessment is crucial for the programme success because it could improve compliance with the established standards, provide stakeholders with an opportunity to voice their opinions, and mobilize more resources to achieve the stated goals (Fédération internationale des Sociétés de la Croix-Rouge et du Croissant-Rouge, 2011).

The objective of this study was to generate evidences that could be used to improve the CE control strategy by exploring the relationships among the different actors involved. To this aim, a stakeholder analysis was carried out to provide a multidimensional visualization of the different actors involved in NHCP implementation (Schmeer, 2000; Sifer, Sulek and Mayer, 2011). A stakeholder analysis identifies the interests of all actors who might influence or be affected by the NHCP. This analysis could help to understand and stimulate the stakeholders' participation at the different stages of the programme, as well as to identify risks and conflicts that may arise, relationships and improvement opportunities (Department for International Development, 2003).

Despite the importance of stakeholder analysis as a monitoring tool, it has been rarely used in research on CE, possibly due to its relative complexity and lack of standardization. Therefore, this study proposes a simplified approach with three assessment criteria, based on the in-depth analysis of stakeholders, to understand the reasons of the NHCP relative failure, and to formulate improvement strategies.

2 Materials and methods

2.1 Ethics approval and consent to participate

Close attention was paid to ethical considerations by following the Guidelines for Research Ethics in the Social Sciences, Humanities, Law and Theology (Norwegian National Research Ethics Committees, 2016). In a formal interview setting, the right to informed consent was strictly observed: verbal consent was sought from the respondents after giving them extensive information on the interview objective, the estimated time required, and the study outcome. Measures to safeguard the responders' anonymity and confidentiality were observed at all times during the fieldwork and data analysis. This work was authorized by the Department of Pathology and Veterinary Public Health Committee, Agronomic and Veterinary Institute Hassan II, Rabat, Morocco, in 2015.

2.2 Study areas

This study was undertaken from 2016 to 2018. Seven Moroccan regions were visited: Rabat (central area, the administrative capital where the ministries are located), Bel Ksiri (near the capital with high CE in humans and animals), Khenifra (one the regions with the highest human CE incidence), Agadir (a region with high CE prevalence in humans and animals, but little studied), and Laayoune, Tantan and Guelmim (three regions with low CE incidence in humans). The seven areas differ in climate, human habits, and geography.

2.3 Field investigations: observations, stakeholders' list, and interviews

First, slaughterhouses, hospitals and provincial health delegations in the study areas were visited and observed. An initial list of stakeholders was established that included the institutions playing a direct or indirect role in the NHCP, as described in the NHCP guide: the Ministry of Health, Ministry of Agriculture, Ministry of the Interior, Ministry of Education, and Ministry of Islamic Affairs. One focus group discussion was organized to gather representatives of all five ministries around the following topics: NHCP creation, organizations and structures that work in accordance or in opposition with them, and their evaluation of the NHCP. This discussion also allowed completing the stakeholders' list.

Then, the semi-structured interview guide was developed. Interviewees were identified based on the initial stakeholder list that was subsequently enlarged through respondent-driven sampling when participants identified other people or institutions that could be included in the study (Patton,

1990). The interview guide was based on the six classical categories of stakeholder analysis: involvement, interest, importance, influence, priority, and power (Schmeer, 2000; Bryson, 2004; Sedereviciute and Valentini, 2011). Among these categories, three can be used to define the stakeholder's role in a programme: involvement, influence, and power. "Involvement" describes the degree of centrality of a stakeholder in the programme. "Influence" is the stakeholder's capacity to mobilize human and material resources to implement the programme, in institutions or in the civil society. "Power" corresponds to the stakeholder's political capacity to interact with other actors to contribute to the programme success or failure. In function of its power level, one actor may challenge other actors, manage other actors, or impulse new orientations to the programme. The other three categories describe the programme place within the stakeholder's activities: interests, priority, and importance. "Interests" include any element that stimulate the stakeholder's involvement. It covers the various stakeholders' activities that could be influenced positively by the programme. "Priority" describes the relative importance given to the NHCP among the stakeholder's different goals. Priority is the result of many symbolic, political, or instrumental factors. Finally, "importance" defines how the programme affects the stakeholder's own income or work. Therefore, "importance" gives an explicit account of the source of instrumental priority.

The interview guide was tested with various stakeholders (one veterinarian, one medical doctor, one breeder, and one slaughterer) to determine whether i) the interviewees were comfortable and understood the questions; ii) the answers provided the sought information; and iii) the interview duration was appropriate (Schmeer, 2000).

The focus group discussion and all semi-structured interviews were face-to-face. The study team was introduced and the study aim was explained before the interviews/discussion. A verbal consent was obtained from each participant, and anonymity was guaranteed to all interviewees. To animate the focus discussion group, a researcher acted as moderator (SA) and a reporter took notes. The discussion and interviews were recorded. The interviews were in Arabic or Berber language, and lasted from 20 to 45 minutes (median time = 32 minutes).

2.4 Workshop for NHCP participatory evaluation

The identified stakeholders were invited to a 1-day workshop in Rabat to share their expertise and experience on CE control. Civil servants were invited from the Ministries of Health (n=2), Agriculture (n=2), Interior (n=1), Education (n=2) and Islamic Affairs (n=1). Researchers from the Faculty of Medicine (n=3), National Institute of Hygiene (n=1), National School of Public Health

(n=2), Hassan II Agronomic and Veterinary Institute (n=5), and Institute of Tropical Medicine Antwerp (Belgium) (n=3) were also invited. The workshop took place in a room, and started with the presentation of the first results from the interviews and their discussion by all invited stakeholders. Participants were then invited to form groups (four to seven participants from different ministries and research institutions). Each group was asked to analyse and summarize the following topics: stakeholders' identification, obstacles to NHCP implementation, coordination between stakeholders, and proposals for NHCP improvement. Each group's analyses were discussed with the other groups. At the meeting end, the results were summarized, discussed and validated by all participants. During the workshop, new stakeholders were identified, and participants in this workshop were asked to be interviewed.

2.5 Second Field investigation

The newly identified stakeholders also were interviewed using the same semi-structured interview guide. In total, 164 interviews were carried out during this study (Table 1): 91 people (internal and intermediate stakeholders) were interviewed before the workshop in Rabat, and 22 and 51 during and after the workshop (external stakeholders), respectively.

Table 1 : ***List of interviews conducted adapted from Schmeer model*** (Schmeer, 2000)***. NHCP: National hydatidosis control program; WHO: World Health Organization; OIE: World Organisation for Animal Health; CE: Cystic echinococcosis.***

Sector	**Sub-Sector**		**Internal / Intermediate/ External stakeholder**	**Number of interviewed representatives**	**Inclusion motif /relation to the NHCP**
International agencies/ Donors	WHO		External	1	External financial and knowledge support
	OIE		External	1	
National Political	Elected politicians, local authorities		External	3	Implementing executive plans and managing municipal budgets
Public entities for NHCP implementation	Central level	Ministry of Health	Internal	1	Members of the inter-ministerial committee for CE control, responsible for the implementation of the NHCP executive plan and the coordination of institutions at the national and local level
		Ministry of Agriculture	Internal	1	
		Ministry of the Interior	Internal	1	
	Provincial and local levels	National Office for Food Safety	Internal	10	Responsible for implementing CE control measures. Receiving orders and budget from central-level public entities
		Health delegations	Internal	11	
		Public Hospitals	Internal	17	
		Local Authorities	Internal	5	
		Municipal Hygiene Offices	Internal	10	
Public entities other than those supervising NHCP implementation	Ministry of Education	Central level	Intermediate	1	Collaborating with the entities in charge of NHCP for the improvement and the implementation of awareness raising campaigns
		School teachers	Intermediate	19	
	Ministry of Islamic Affairs	Central level	Intermediate	1	
		Imams of mosques	Intermediate	14	
Private Sector	Associations	National Association of Cattle Breeders	External	5	Directly affected by the economic losses caused by CE. Holding an interest in controlling this zoonosis
		National Association of Ovine and Caprine Breeders	External	4	
	Private-sector physicians		External	14	Can protest and lobby for fund mobilization
	Private-sector veterinarians		External	12	
	Researchers		External	11	
	Slaughterers		External	22	
Total				**164**	

2.6 Data analysis

All interviews were transcribed in their original language and then translated into French, the only language known by all research team members. For the present analysis, selected excerpts were translated into English. Recordings were listened and transcripts were reviewed by the research team to check their quality and completeness. Transcripts were then analysed by software-assisted textual analysis, using the RQDA package in the R software. Responses were coded and grouped in six themes: involvement, interest, influence, priority, power and importance. For each category, subcategories were created to group similar responses. These categories and subcategories were analysed in the interview of each stakeholder. For presenting the results in the form of graphs, the answers, grouped in qualitatively described subcategories, received a standardized notation that translated the stakeholder's status for each of the six themes (Table 2). The responses concerning involvement and power (for the stakeholder's role-centred variables) and importance and priority (for the programme place-centred variables) were noted using a scale from 0 to 3. The responses concerning interest and influence were noted by summing the points ascribed to the different categories (each category had the same weight). When several actors from the same institution were interviewed, their individual answers were semi-quantified and then, the mean value for the institution was calculated.

Among all possible analyses generated by the responses concerning the six themes, three criteria were defined to describe the programme place in the stakeholder's activities and the stakeholder's role in the programme (Figure 1). Each criterion combined one theme centred on the stakeholder's role and one theme on the programme's place. The first assessment criterion was the appropriation of control measures. Appropriation was assessed by clustering measures according the their score of "interest" for the stakeholders and of their "involvement" in their implementation. Values mobilized were the means of each measure for all stakeholders. The second assessment criterion, termed "political agency", mapped the stakeholders' diversity according to their "power" on other stakeholders and the "priority" they ascribed to CE control. The third assessment criterion, termed "socio-technical agency", mapped the stakeholders' diversity according to their "influence" on the programme implementation (mobilization of resources and people) and the programme "importance" for their own income or work. For these last two criteria, the values were the means per stakeholder for all control measures.

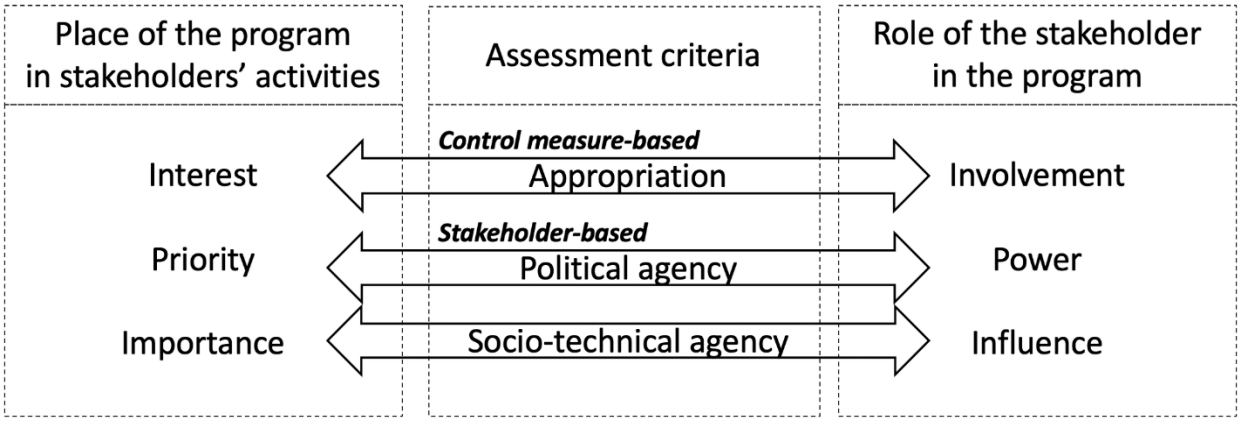

Figure 1: Analytical framework to define the three assessment criteria from the two-dimensional mapping of stakeholders and measures based on the six classical variables that compose the stakeholder analysis.

Table 2 : categories and codes used for sub categories and notation assigned to each subcategory

Category	Subcategories	Assigned notation	Notation type
Stakeholder's role within the program			
Involvement	Not involved: their institution has no role to play	0	Scale of notation
	Little involved: their institution plays an indirect role	1	
	Involved: their institution plays a fundamental role	2	
	Highly involved: their institution is responsible for the implementation of NHCP	3	
Power	No power	0	
	Challenge other actors	1	
	Manage other actors	2	
	May propose new procedures	3	
Influence	Indirect influence through other actors	0	Points to be summed
	Mobilization of resources	1	
	Mobilization of public institutions	1	
	Mobilization of civil society	1	
Program's role within stakeholders' activities			
Priority	NHCP has no place in their projects	0	Scale of notation
	CE control is included in their program but it is not considered as a priority	1	
	NHCP is included in their program and it is considered among the priority	2	
	CE control is a top priority	3	
Importance	NHCP has no importance	0	
	The control of this disease does not influence their activity but it can improve the quality of work of their partners	1	
	NHCP can improve their quality of work or income	2	
	NHCP is very important for their quality of work and income	3	
Interests	Economic: disease control could improve economic prospects, benefit, improve the quality of some products	1	Points to be summed
	Social: the control of the disease improves the quality of life, the wellbeing	1	
	Work: improves working life, people will be more satisfied with their work	1	
	Environment: environmental protection, stop the spread of the disease, prevent infection of the final and intermediate hosts	1	
	Health: improve community health, prevent infection in humans	1	
	Safety and security: disease surveillance programs can improve the health of at-risk populations and prevent economic losses in animals	1	

2.7 Data validation

The criteria proposed by Guba and Lincoln for judging the validity of qualitative research were followed to assess the study results: credibility, transferability, dependability and confirmability (Lincoln and Guba, 1985). All team members validated the data credibility because the data collected were enough to understand the research subject from the point of view of all interviewed participants. Transferability was respected by carefully describing the research context and process in order to identify the result part/dimensions that can be transferred to (or compared with) other zoonoses or other regions or countries. Dependability was guaranteed by the structured method of data codification and classification by the construction of themes and sub-themes. Confirmability was ensured by the neutrality of the collected data and their interpretation.

3 Result

3.1 Stakeholders' identification

Stakeholders were categorized in internal, intermediate and external stakeholders. Internal stakeholders are responsible for NHCP implementation; intermediate stakeholders work in collaboration with the internal stakeholders; and external stakeholders may provide funds, be in competition with the programme, or show a special interest for CE control without being directly involved in the NHCP (19) (Figure 2). A set of institutional stakeholders constituted the internal and intermediate stakeholders. The Ministries of Health, Agriculture and the Interior, which organized the NHCP and supervise its implementation, represented the internal stakeholders. The Ministries of Education and Islamic Affairs and the media, which work in collaboration with the inter-ministerial CE control committee and contribute to the dissemination of messages concerning CE, were considered as intermediate stakeholders. WHO, which funds the NHCP, was considered an external stakeholder that provided inputs to the programme. OIE (World Organization for Animal Health) was not included in the NHCP, but could contribute funding or knowledge, and therefore was classified as external stakeholder. Individuals and field actors were considered as external stakeholders. This group included stakeholders that suffered CE-linked economic losses, such as slaughterers (loss of infected offal) and breeders (animal productivity and economic losses). Breeders were represented by large associations: National Association of Cattle Breeders (ANEB) and National Association of Sheep and Goat Breeders (ANOC). Elected politicians were considered to be external stakeholders because they manage municipal budgets and allocate it to

uses that might compete with CE control. Finally, researchers, private-sector physicians and private-sector veterinarians also were included in the external stakeholder category because they are in direct and almost permanent contact with the population, show relevant skills and knowledge, and can convey messages to the population, but are not formally involved in the NHCP..

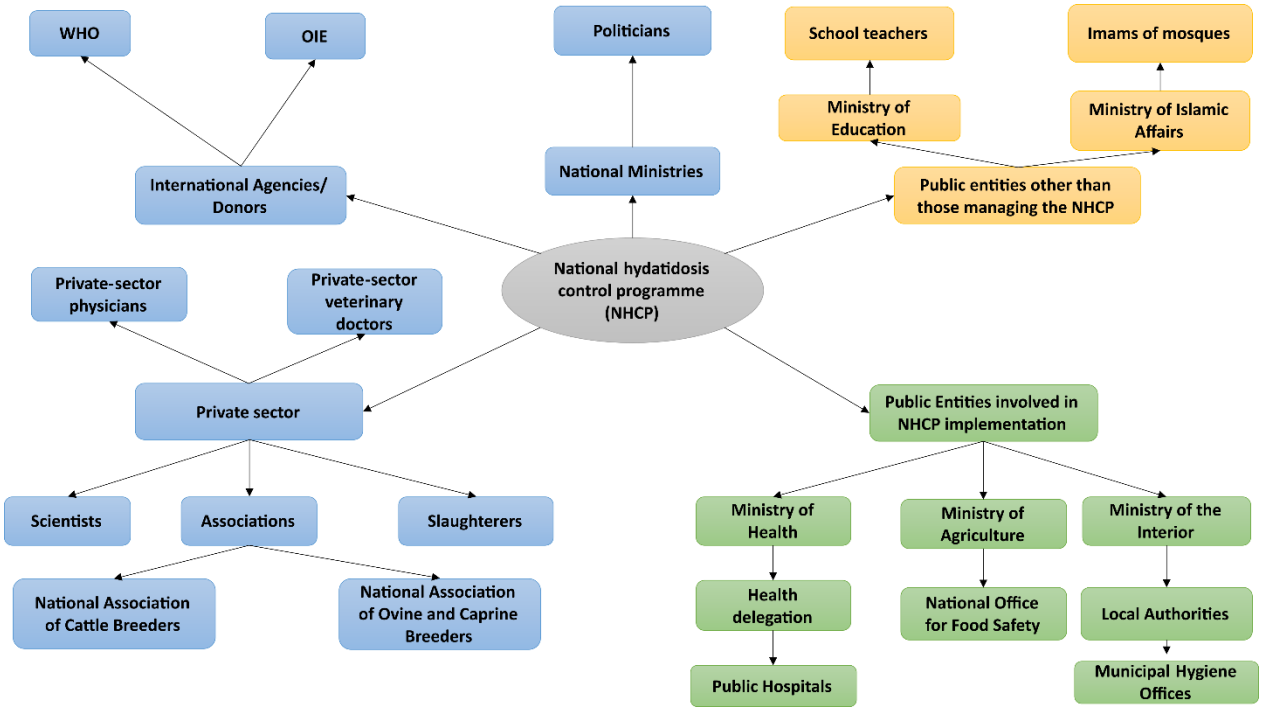

Figure 2: ***Stakeholders' map.*** *Green: Internal Stakeholders; Orange: Intermediate Stakeholders; Blue: External Stakeholders*

3.2 Measure of appropriation: stakeholders' interest and involvement

The NHCP is based on six control measures that could be categorized in two groups on the basis of the stakeholders' degree of interest and involvement: i) appropriated measures (offal seizure, slaughterhouse development, and treatment of human cases) for which the stakeholders felt well involved and stated interests, and ii) neglected measures (control of the dog population, dog deworming, and awareness raising) that did do not attract the interest of the stakeholders who did not feel involved in their implementation (Figure 3).

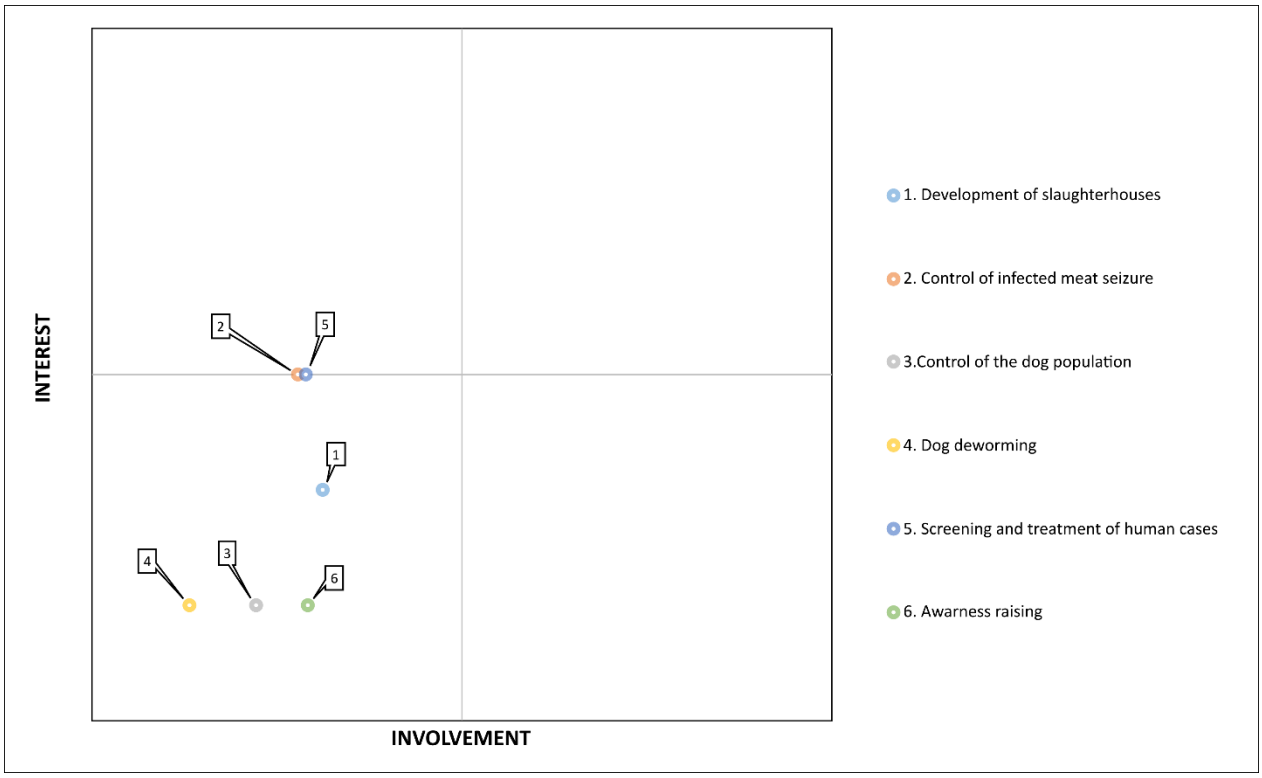

Figure 3: Scatter plot of the six NHCP measures according to the stakeholders' interest and involvement in their implementation

3.3 Stakeholders' socio-technical agency: influence on the NHCP and programme importance

Each stakeholder could be defined in function of its influence on the NHCP and the programme importance for that stakeholder (Figure 4). Most internal stakeholders were concentrated in the "high importance - high influence" group (Fig. 4B), with the exception of the municipal hygiene offices for which the programme was less important, although they had high influence (Fig. 4D). Some stakeholders considered the NHCP very important, but had low influence on its implementation (i.e. slaughterers and breeders' associations) (Fig. 4A). Intermediate stakeholders were all in the "low influence - low importance" group (Fig. 4C) because their role in NHCP was focused on improving the quality of the work performed by internal stakeholders, and their influence was based on the civil society mobilization. External stakeholders who provide inputs to the NHCP (OIE and WHO) had a medium influence and medium importance. External stakeholders, who could compete with the programme's resources (i.e. politicians) or who provided inputs in the form of active participation in awareness raising (i.e.

researchers, private-sector physicians and private-sector veterinarians) were in the “low influence - low importance” group (Fig. 4C).

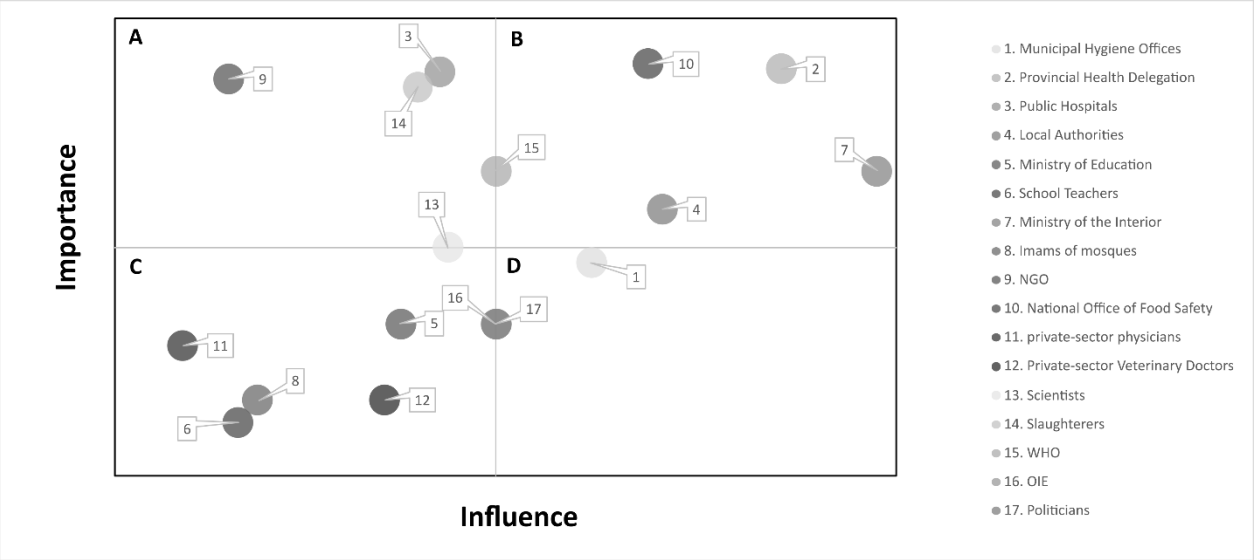

Figure 4: Scatter plot to classify the stakeholders according to their influence on NHCP implementation (mobilization of resources and people) and the importance they ascribe to the programme in the framework of their activities.

3.4 Stakeholders’ political agency: NHCP priority level and stakeholders’ power

Stakeholders could also be classified on the basis of the priority they ascribed to the NHCP in their activities and their power (Figure 5). Internal stakeholders had huge power in the NHCP, but only the ONSSA considered CE a high priority. Political stakeholders had a large power, but they did not consider NHCP a priority. Some external stakeholders (slaughterers, WHO and municipal hygiene offices) thought that NHCP was a high priority, but their power was limited. Intermediate stakeholders and the other external stakeholders were in the “low power - low priority” group.

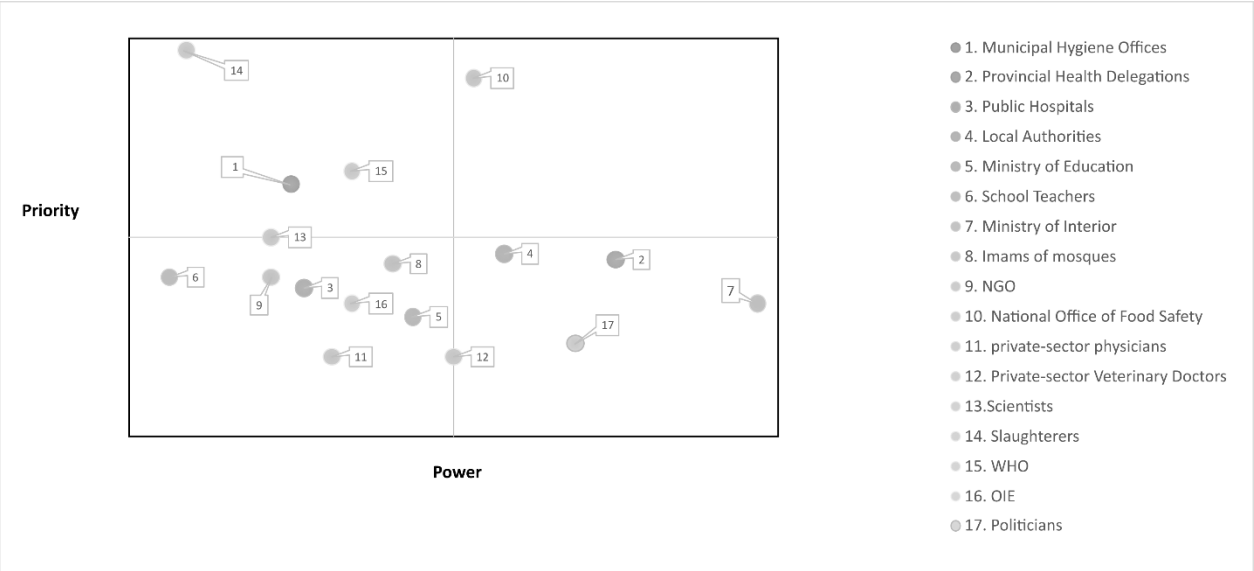

Figure 5: Scatter plot showing the stakeholders' distribution according to their power on the NHCP and the priority they ascribe to the programme in the framework of their activities.

4 Discussion

The burden of human and animal CE is very high in Morocco, despite the nationwide control efforts through the NHCP, officially launched in 2007 (Mansouri *et al.*, 2015). Here, a stakeholder analysis was carried out to better understand NHCP challenges in view of its improvement. By semi-quantifying qualitative data, this method allowed visualizing the results, thus guiding the data analysis and result communication. The study revealed a complex institutional network of public- and private-sector stakeholders. Indeed, by adopting a problem-centred viewpoint, the stakeholder analysis transcends the boundaries of the economic, political, administrative and citizen realms by joining them within analytical categories (Bonnafous-Boucher and Pesqueux, 2006). By highlighting the diversity of actors, it revealed the complexity of a programme targeting a zoonotic disease in which both animal and human health actors are implicated, and covering public health, economic activity (animal production), and environmental management (roaming dog populations). This intermingling entails an additional complexity due to the diversity of required behavioural changes that might lead to gaps in awareness, to conflicts between individual interests and public good, and that might be hindered by cultural factors and socio-political divides among the involved stakeholders.

The list of stakeholders identified in this study was much larger compared to those cited in the NHCP. The identification and the involvement of all stakeholders in a project are strategic and

essential for its effectiveness (WHO/OIE, 2002; Culyer, 2005). The current NHCP failed to identify and involve all external stakeholders (OIE, slaughterers, breeder associations, local politicians, researchers, private-sector physicians and private-sectors veterinarians), with the exception of the WHO that contributed to the funding. Although the internal stakeholders are obvious key actors in leading the project, their effectiveness relies massively on external stakeholders who play the role of supporters and promoters (Lewis, Hamel and Richardson, 2001). Therefore, the sustained involvement of external stakeholders is necessary for a project success (Schlange, 2006; Zott and Huy, 2007). Overall, the close relationships between internal and intermediate/external stakeholders promote the development of knowledge, complementary resources, and social networks, constituting means and processes for effective governance (Morsing and Schultz, 2006). For instance, in the present case, the collaboration with academic researchers could lead to the development of new technologies and innovations in CE control (Marcotty *et al.*, 2013).

The classification of measures according to their degree of appropriation highlighted the relative neglect of some of them (i.e. dog population control, dog deworming, and public awareness raising). In this case, like in any control matrix, the lack of commitment or the poor execution of measures can seriously hinder the whole project (OMS and CDS, 2011). Indeed, the complex lifecycle of zoonotic diseases, especially those involving multiple non-human animal species, entails the need of concerted actions at the different levels of the cycle to interrupt it in an effective manner. Similarly, in rabies control programmes, the management of roaming dogs is often a neglected area or is poorly coordinated with the overall control strategy (Direction de l'Epidémiologie et de Lutte contre les Maladies, 2018).

The classification of stakeholders according to their political and socio-technical agencies revealed a generally high agency of some internal stakeholders from the animal health sector (ONSSA). The agency of internal stakeholders from the public health sector was limited by the low priority they ascribed to the NHCP. Finally, internal stakeholders from local authorities and the Ministry of the Interior, who are responsible for the maintenance of infrastructures and the local enforcement of the programme, displayed an even lower agency, despite their influence and power, due to the weak importance and priority they ascribed to the NHCP. Besides impairing their own effectiveness as internal stakeholders, this affected also their ability to elicit the participation of external stakeholders (Bouhafs, Ilana ; Ozcaglar-Toulouse, 2018). Important dynamic effects of stakeholders' engagement might be expected from a better

congruence of the central actors in the programme implementation (Morsing and Schultz, 2006). This might contribute to reduce a second important defect identified here, namely the neglect of actors with important interests in the NHCP. To create this congruence, a better alignment is needed between the stakeholder's power or influence and the NHCP priority or importance for that stakeholder. Particularly, stakeholders with high power or high influence, but who ascribe a low priority or importance to CE control, can slow down NHCP implementation. The neglect by stakeholders may lead them to passivity in the control programme, or even to hinder its implementation. Mayers proposed a general strategy for managing relationships to mitigate the impact of such stakeholders and to guarantee the interests of neglected stakeholders (Mayers, 2005). Therefore, the sustainable improvement of a programme requires some changes in the power relationships among its actors. However, this is not easy to put in place because each change of power leads to a new equilibrium that depends on the possible development of technical, economic and social relationships (Crozier, 1960).

A possible strategy to improve the stakeholders' involvement could be the constitution of a multi-stakeholders' working group that must take into account the interests, position and specific needs of each stakeholder, and that will obtain their active support by increasing their power and leadership (Schmeer, 2000). Besides the multi-stakeholder group, regrouping stakeholders who share the same fields of action will allow sharing knowledge and experiences, thus promoting the multi-stakeholder group's work. Intersectoral collaboration is needed to improve the control of zoonoses (Marcotty *et al.*, 2013). Collaboration among stakeholders could be promoted and managed by a central office that includes representatives of the different structures. This organization can meet the technical, coordination and communication needs. The participatory approach followed in this study made it possible to visualize the process of CE control through its stakeholders' viewpoints. Table 3 summarizes the NHCP weaknesses revealed by this study, and the proposals generated from the results for improving it.

Table 3: Weak points of the current NHCP and proposals for improving them

Weak points of the current NHCP	How to improve them
Not all stakeholders were identified by the NHCP	Include all stakeholders identified in this study in the new policy and action strategies
Stakeholders identified belong to different spheres (public health, animal health, private sector, politicians ...)	Manage the stakeholders' diversity by creating arenas of concertation. Understand each stakeholder's goals and interest in the NHCP, highlight the added value of collaboration for each of them.
Some CE control measures are neglected by stakeholders	Revise the incentives for stakeholders who fulfil their duty. Take into account their priorities.
NHCP is not a priority for key stakeholders with high power and influence	
The management of all stakeholders is difficult due to their high number and variety (different ministries and structures)	Create working groups of stakeholders who belong to similar spheres. Each working group will focus on one or more aspects/measures of CE control. Create a multi-stakeholder group that should benefit from the output of these working groups.
NHCP central management is difficult because the power/influence balance is different among stakeholders	Creation of a central office where each stakeholder has a representative. A stakeholder with high interest, high priority, high power and high involvement would be a good candidate to manage this central office.

5 Conclusion

This study provides an operational understanding of the stakeholders' role and potential in CE control in Morocco and identified stakeholders from different spheres (political, economic and social) who were neglected during the planning and implementation of the current NHCP. This study illustrates the complexity of controlling a zoonosis that results in part from the need to involve many different actors, well beyond the public and animal health sectors. Useful actors may be neglected or interactions between the actors involved may be impaired due to their different priorities or power relationships. Therefore, an ill-functioning collaboration cannot produce the needed field outcomes. Proposals were generated during this study to improve the NHCP, including working groups. This study proposes a structured analysis strategy to understand these interactions and inform their improvement. As a tool for evaluation

and situation analysis, it may inform practical decision-making for zoonosis control. Applied in a systematic way in a diversity of settings, this methodology could generate cross-case studies and help to develop international recommendations to control zoonoses according to the One Health concept.

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Chapitre 4

Amélioration du programme national de lutte contre l'hydatidose/échinococcose au Maroc

Article soumis

Préambule

Le projet abritant ce travail de thèse vise à évaluer une nouvelle approche de lutte contre l'hydatidose, basée sur la vaccination des ovin (via le vaccin EG95), le traitement anthelminthique des chien et les campagnes de sensibilisation/éducation de la population. Les études précédentes ont mis en évidence les contraintes émergent de la mise en œuvre, tenant notamment au rapport que les différents acteurs entretiennent avec les mesures qui les concernent. Cette quatrième étude propose ainsi d'explorer l'acceptabilité sociale et la faisabilité de cette nouvelle approche de lutte, à la fois chez les responsables de santé humaine et animale et la population. En utilisant une approche qualitative, nous avons pu ressortir les recommandations proposées par les professionnels et la population.

The feasibility and acceptability of a new integrated approach to control cystic echinococcosis in Morocco: vaccination of sheep and anthelmintic treatment of dogs

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Abstract

Cystic echinococcosis (CE) is a common parasitic disease in the world, especially in poor and developing countries. In Morocco, CE is a major zoonosis, despite the national control program running since 2007. To improve CE control strategy, vaccine EG95 trials (in lambs) associated with anthelmintic treatment of dogs have been conducted in the Mid Atlas, the most endemic region in the Morocco. This study presents the analysis of the feasibility and social acceptability of this strategy. The purpose is to trace an approach for the elaboration of a guideline to conduct such new intervention. A qualitative research approach was adopted to carry out this study. Eleven focus group discussions were conducted with breeders, women, and local authorities and sixteen in-depth individual interviews were conducted with private veterinarians and officials from structures responsible for the potential implementation of the CE control program. The recordings were transcribed and analyzed with R software, using RQDA package. Credibility, transferability, dependability and confirmability were the criteria of validation for this qualitative research. This study showed that participants' views on sheep vaccination and anthelmintic treatment were divided between acceptability and concerns. The participants proposed solutions for a better implementation of this strategy. The application of an approach to improve CE control requires the implementation of several public policies targeting the different aspects of this zoonosis, and

respecting the socio-cultural pillars. Bringing together the views of the communities and the professionals, this study traced the main lines to succeed in the new CE control approach in the short and long term.

Author Summary

Cystic echinococcosis (CE) is a public health problem in many developing countries. Several countries adopted CE control programs; however, many of these programs failed. In Morocco, like the other Mediterranean countries, CE control programs failed to eliminate this zoonosis. Looking for alternative solutions has become necessary. In this context, sheep vaccination trials associated with the treatment of dogs are underway in Morocco. Theoretically, this strategy can be effective to control CE in 15 years. The aim of this study is to seek a strategy for an adequate implementation of these new CE control measures in Morocco. This study proposed an approach to analyze and to inform an international guidance for the implementation of zoonosis control programs.

Keywords: Cystic echinococcosis (CE); Morocco; EG95 vaccine; Feasibility; Acceptability.

1 Introduction

Cystic echinococcosis (CE) is a neglected major zoonosis, striking mostly developing countries (Singh *et al.*, 2014). Caused by the larval stage of the tapeworm *Echinococcus granulosus*, CE is an intestinal parasite that usually infects dogs as a definitive host. Eggs of this tapeworm are eliminated with the dog feces and transmitted to the intermediate hosts, human and ruminant (especially sheep), buy ingesting contaminated water or food (Thompson and McManus, 2002; Budke, Deplazes and Torgerson, 2006).

By dint of the new technology, the diagnosis and treatment of CE have been improved in humans and animals; however, CE persists in several countries, especially the Mediterranean countries (Battelli, 2004; Moro and Schantz, 2007). The first cystic echinococcosis control program was introduced in 1863 in Iceland, however, apart from two regions in Chile and Argentina, it is only islands that have been able to obtain positive results (Iceland, New Zealand, Tasmania, Falklands and Cyprus) (Craig and Larrieu, 2006). The reasons for the failure of CE control programs are multiple, including the premature withdrawal of funding, the underfunding of the implementation of control measures, the difficulty of managing the dog population and the presence of political unrest (Craig and Larrieu, 2006). Hypothetical CE control scenarios were investigated using mathematical simulation models. It was concluded that anthelmintic treatment of dogs is a primary

strategy, but at least 60% of dogs should be treated every 3 months (Torgerson, 2003). The management of the dog population is difficult to implement, especially in developing countries, where the population is not interested in dogs treatment. Vaccines are often used to control parasitic and infectious diseases. In the case of zoonosis, preventive veterinary treatments not only protect the health and well-being of animals, but also reduce the risk of their transmission to humans. In this context, a vaccine using the recombinant protein EG95 was developed, and vaccine trials in Australia and Argentina proved its effectiveness (Heath *et al.*, 2012; Larrieu *et al.*, 2013, 2015). CE control intervention combining sheep vaccination and anthelmintic treatment of dogs is an effective strategy (Torgerson, 2006). Theoretically, this strategy will allow CE control in about 15 years (Torgerson, 2003, 2006).

In Morocco, CE is endemic, despite the national program of CE control (Aubry, 2013). The economic losses caused by this zoonosis in Morocco are estimated at 73 million United States dollar, which represents about 0.07% of the country's gross domestic product (DDP) (Saadi *et al.*, 2020). Its prevalence of infestation has been estimated in dogs, which reach from 23.5% to 38.8% and 51.3% to 68.5% respectively, in owned and in stray dogs (Amarir *et al.*, 2020). The CE prevalence in humans is estimated at 1.9% (Chebli *et al.*, 2017). Concerning CE in livestock, CE prevalence at slaughterhouses was 42.9% in cattle, 11.0% in sheep, and 1.5% in goats (I El Berbri *et al.*, 2015). The high number of dogs, and the slaughtering practices allowing dogs to have access to condemned offal, are the major elements of the persistence of CE in Morocco (Ikhlass El Berbri *et al.*, 2015; Bardosh *et al.*, 2016). In front of this situation, Moroccan authorities are looking for alternatives to improve the control strategy. In this context, a five-year research project entitled "Strengthening the strategy to control the zoonotic Cystic echinococcosis in Morocco: veterinary, economic and sociological aspects" was launched in 2015. This project aimed at carrying out field trials of sheep vaccination using the EG95 vaccine associated with anthelmintic treatment of dogs in the Mid Atlas, during the period 2016-2020. The aim of this study is to evaluate the acceptability of this new CE control strategy based on sheep vaccination (EG95 vaccine) and anthelmintic treatment of dogs. A qualitative research approach as applied to investigate the views of the program managers and the target population on the proposed control strategy.

2 Materials and Methods

2.1 Ethics approval and consent to participate

Close attention was paid in respecting ethical considerations following the instructions of Guidelines for Research Ethics in the Social Sciences, Humanities, Law and Theology (Norwegian National Research Ethics Committees, 2016). In a formal interview, setting the right to informed consent was strictly observed: verbal consent was sought from the respondents giving them as much information as possible about the purpose of the interview, the estimated time required, and the outcome of the study. Verbal consent was chosen instead of written one because the later implies a signature, which could embarrass the interviewees or make them anxious. It was explained that participation was voluntary. No explanation was asked of those who refused to be interviewed. Anonymity and confidentiality of the respondents were respected during the fieldwork and data analysis process. This work was authorized by the ethical committee of the Department of Pathology and Veterinary Public Health, Agronomic and Veterinary Institute Hassan II; Rabat, Morocco, in 2015.

2.2 Study area

The Mid Atlas is the most endemic region of CE in human and livestock in Morocco (Azlaf and Dakkak, 2006; Chebli *et al.*, 2017). The study was carried out in the province of Khenifra (Figure 1), because according to the records of the Ministry of Health, the surgical incidence in this province is higher compared to the other region in Mid Atlas, and the sheep farming plays a fundamental role in the economy of this province (Direction Général des collectivités Locales, 2015). The population is mostly Amazigh and Muslim, and it is among the poorest regions of Morocco (Haut-Commissariat au Plan du Maroc, 2014). Five sites were selected based on the importance of sheep farming and the availability of selected participants: Khenifra center, M'rirt, El Kbab, Midelt and Zaouiate Ait Isshak.

Figure 1: **Khenifra province (in green)**. *(Source: Wikimedia commons*: https://commons.wikimedia.org/wiki/File:Khenifra_in_Morocco.png?uselang=fr)

2.3 Study design

The data collection was done during a timeframe of three years (from 2016 to 2018), which correspond to the period of EG95 vaccine trials. The focus group discussions (FGDs) and in-depth individual interviews (IDIs) collection took place at the same time as the sheep vaccination process and anthelmintic treatment of dogs. A qualitative research approach was adopted using the non-probabilistic method of snowball sampling to recruit the units of the sample by selecting a group of individuals corresponding to the desired profile, as described here below, and then asked to identify the others (Patton, 1990). The first list of recruits included doctors, officials of the health delegation, local authorities introduced by the municipal hygiene office (BMH), decision-makers and officials of the National Office of Sanitary Security for food safety (ONSSA). These people were identified because they were responsible for the implementation of CE control program. Breeders were also part of this participant list as they would be the main beneficiaries of this program as well as the ones to adopt or not the vaccination of sheep and/or the treatment of their dogs. Veterinarians of the ONNSA identified in turn the private veterinarians and they, together with doctors, identified wives of the breeders.

FGDs and IDIs were conducted in the different study sites according to the participant category. Separate homogeneous FGDs were organized with breeders, women and local authorities because

these groups have different tasks and responsibilities in the sheep breeding system and therefore potentially different perceptions and practices regarding CE control measures. IDIs were conducted with private veterinarians in their respective clinic. To avoid the risk of biases due to their power relationships, doctors and officials of ONNSA, of both the health delegation and of BMH, were also interviewed individually. Additionally, collecting data by using different methods and including a maximum variation of participant categories are triangulation procedures which are likely improving the quality and validity of the data (Fusch and Ness, 2015b). A total of 11 FGDs and 16 IDIs were performed. Six FGDs with women, five FGDs with breeders, and one FGD with local authorities. Concerning IDIs, three were done with veterinary technicians of ONSSA, three with veterinarians of ONSSA, four with doctors, two with officials of the health delegation, five with private veterinarians and 2 with BMH (Table 1).

Table 1: Characteristics of the focus groups (FGDs) and individual interviews (IDIs) conducted to collect data

Study Site	Category	Number of interviews	Number of participants	Year of making interviews
FGDs				
M'rirt	Breeders	2	18	2016
	Women	1	13	2016
Zaouiate Ait Isshak	Women	1	10	2016
El Kbab	Breeders	1	8	2017-2018
	Women	3	36	2017-2018
Khénifra centre	Breeders	2	24	2017
	Locales authorities	1	6	2017
Total		**11**	**115**	
IDIs				
Zaouiate ait isshak	Veterinary technician of ONSSA	1	1	2017
Khénifra center	Veterinary technician of ONSSA	1	1	2017
	Veterinarian of ONSSA	3	3	2017
	Doctors	4	4	2017-2018
	DELM	2	2	2017
	Private veterinarian	3	3	2016-2017
	BMH	2	2	2017
Midelt	Private veterinarian	1	1	2017
M'rirt	Private veterinarian	1	1	2017
	Veterinary technician of ONSSA	1	1	2017
Total		**19**	**19**	

2.4 Data collection

Three interview guides were developed: one to animate the discussions with breeders and women, one for private veterinarians, and a third one for ONSSA officials, doctors, health delegation and local authorities (Table). The topic and interview guides were tested in another province (Sidi Kacem) in Bel Ksiri village, with private veterinarian (n=1), veterinarian of ONSSA (n=1), doctor (n=1) and two groups of breeders. The aim was to determine whether the participants understood all the questions and if the duration of the discussion and interview was appropriate (Schmeer, 2000). All FGDs and IDIs were conducted face-to-face and we required verbal consent of the person interviewed prior to starting. Verbal consent was chosen instead of written one because the later implies a signature, which could embarrass the interviewees or make them anxious. It was well explained that participation was voluntary. In order to protect the right to privacy, no explanation was asked of those who refused to be interviewed. To animate the discussions, a moderator (SA) was leading the discussion and a reporter (KS) was taking notes. All the interviews were conducted in a quiet room delivered by local authorities and associations. They were recorded both by an audio recorder and a video camera in order to facilitate the transcription and return to the videos to review the reactions of the different interviewers. All participants agreed to be filmed except one doctor. FGDs and IDIs were conducted in Arabic language, except FGDs with women, which were conducted in Berber. The duration of the discussions (FGDs and IDIs) varied between 20 and 45 minutes.

Table 2: Summary of topic guides

Common topics: -Acceptability and feasibility of the EG95 vaccine -Acceptability and feasibility of the anthelmintic treatment of dogs -Constraints -Suggestion for the implementation of the approach based on EG95 vaccine for sheep, anthelmintic treatment of dogs, awareness raising
ONSSA, doctors, health delegation and local authorities topics: -Evaluation of CE in human and animals -The perceived success of the CE control program
Private veterinarians topics: -Acceptability to participate in the implementation of the CE control program -Requirements to participate in the implementation of the CE control program
Breeders and women topics: -Perception of CE -Knowledge of CE economic impact, specially, losses in productivity in livestock

2.5 Data analysis

The videos and audio recordings were transferred to a computer, and shared with the team. They were transcribed and translated from Arabic and Berber into French. The notes and transcriptions were anonymous and checked by the interviewer (SA) and the reporter (KS). To improve reliability, another team researcher (SH) examined the transcripts. The transcripts were loaded in the R software to be analysed using the RQDA package. The coding of the anonymous transcripts was done independently by the interviewer and the reporter. Provisional codes (themes) were developed at the beginning: success/failure of the current CE control program, acceptability and feasibility of each proposed measure. Proposals and constraints were added as emerging themes during the analysis process. The themes were grouped in two sub-categories: argumentations and incentives. The coding tree process is presented in Figure 2. The results were then compared between the different participant categories and between the different study sites.

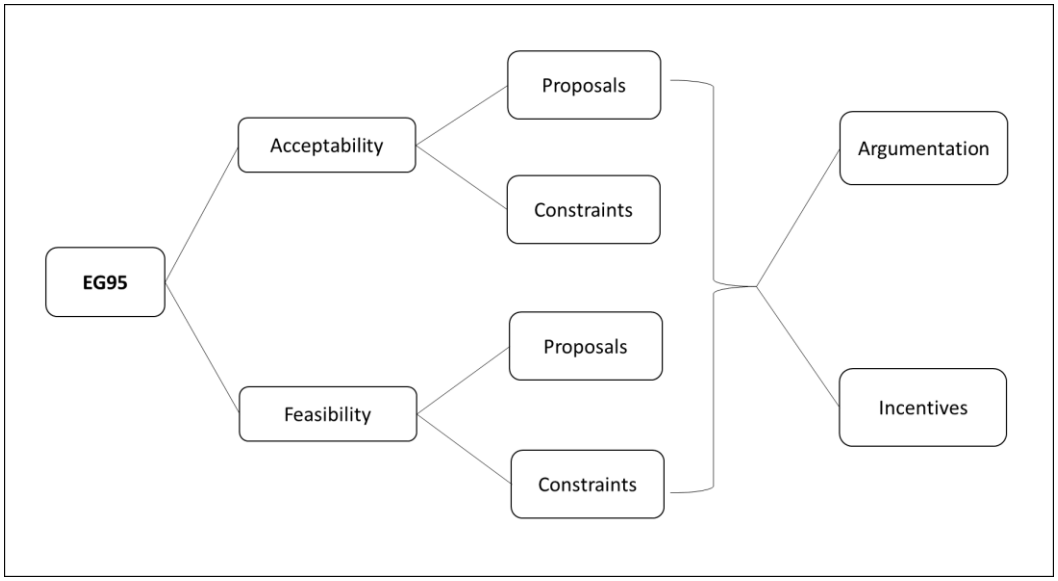

Figure 2: Coding tree for the theme "EG95 vaccine"

2.6 Data validation

The biggest criticism that arises when adopting the qualitative approach is the validation of the data. Unlike quantitative research, it is difficult to prove the accuracy or falsity of an observation. Therefore, Guba and Lincoln proposed four alternative criteria for judging the merits of qualitative research: credibility, transferability, reliability and confirmability (Lincoln and Guba, 1985). The whole team validated the credibility of the results obtained since the data collected was sufficient to understand the subject of this research from the point of view of all participants. Transferability

was respected by carefully describing the research context and process, and the results can be transferred to study on other zoonosis in another regions or countries. Dependability was guaranteed by the structured method of codification and classification of the data by the construction of themes and sub-categories (Figure 2). Confirmability was ensured by the neutrality of the data collected and their interpretation. Figure 3 shows the validation process.

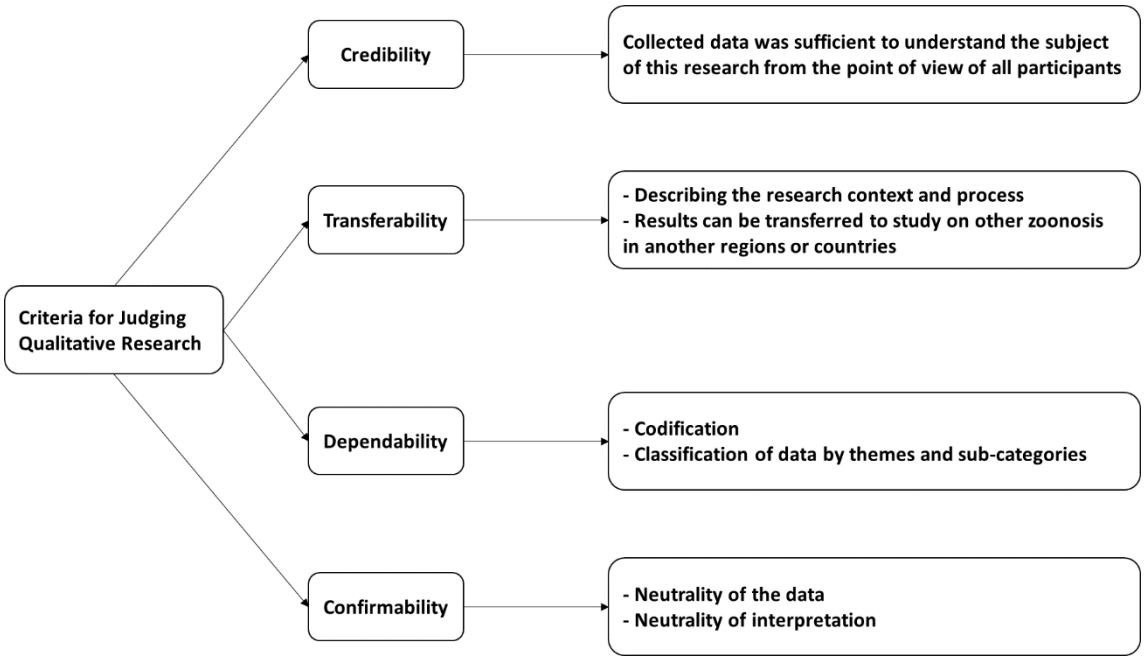

Figure 3: ***Criteria used to validate the qualitative approach of this study***

3 Results

3.1 Perception of existing CE control program

ONSSA veterinarians considered that the program had failed since the quantities of seized cysts were still important. Technicians of ONSSA working at the slaughterhouses reported that the prevalence of CE decreased during these last ten years, while according to the ONSSA veterinarians, it did not. They further explained this decrease by the fact that the younger animals were the most slaughtered, and because CE is a chronic disease, which takes years to develop.

"I work in this slaughterhouse, it's been more than 19 years and I find that the number of cysts found is not as important as before." (IDI/ Technician of ONSSA/ M'rirt)

"The CE control program did not give the desired results. It was expected that with this program we will be able to reduce the incidence by 50%, but that was not the case." (IDI/ ONSSA veterinarian/ Khenifra center)

For medical doctors, the program failed because the number of human cases per year remained stable. During the FGDs with the local authorities, the participants expressed their dissatisfaction with the CE control program.

"The truth is that CE is still there! I see the reports, there is no decrease" (IDI/ Official of BMH/ Khenifra center)

For ONSSA veterinarians, medical doctors, BMH officials and local authorities, they thought that the program failed to achieve its objectives because the implementation of the measures described in the guide was "difficult if not impossible". Private veterinarians believed that the program was "not compatible with Moroccan infrastructure". All the participants declared the need to find other solutions to improve the program.

"How can this program be successful while the axes of this program include the restructuring of slaughterhouses?! Because in that case, it is necessary to reorganize all slaughterhouses of the country!" (IDI/ Private veterinarian/ Khenifra center)

3.2 Proposals for a new approach

3.2.1 Vaccination of sheep

ONSSA veterinarians had different views about the EG95 vaccine. Some of them thought that this vaccine was a very acceptable solution if its effectiveness was well proven. Others expressed their concerns about the ineffectiveness of vaccination if sheep is the only species covered, pointing to the need to other species. Local authorities were in favor of vaccinating sheep. Medical doctors said that immunization would be a good way to cut the parasite live cycle. For private veterinarians, the vaccine was perceived as a good solution; however, they thought that breeders would not agree to pay to vaccinate their sheep, especially since CE is asymptomatic.

"I think this vaccine is a good solution to fight against hydatidosis. Breeders will only accept the vaccine if they see it as useful." (IDI/ ONSSA veterinarian/ Khenifra center)

Breeders told that they generally vaccinated their livestock against diseases causing a high mortality and morbidity such as bluetongue, foot-and-mouth disease and enterotoxaemia. For them, the vaccines they were already using were expensive and they would not have the means to add a new vaccine to their vaccination schedule. Breeders did not consider CE as a serious disease. They said that they would not do it because CE was not a danger to their livestock. According to women, their husbands preferred to invest on things that has visible effects. Women proposed to run a free campaign to vaccinate sheep.

"We vaccinate our sheep against enterotoxaemia because it causes a lot of mortality. Already this vaccine is expensive. Hydatidosis does not do anything to our animals ?! Why are we going to buy a vaccine for that?!!!" (FGD/ Breeders/ El Kebab)

For ONNSA and private veterinarians the vaccine must be subsidized and incorporated with another vaccine like enterotoxaemia. They also mentioned that it was necessary to carry out a good awareness raising campaign to demonstrate to the breeders the production losses caused by CE. Breeders were completely unaware of production losses caused by CE and accepting a new vaccine would first require them to see other breeders using it to be reassured.

"It takes time for breeders to get used to this vaccine. The breeder will accept it if they are well informed about the damage and losses that this disease could cause." (IDI/ Private Veterinarian/ M'rirt)

3.2.2 Anthelmintic treatment of dogs

When the participants were asked to compare the use of anthelmintic treatment of dogs with other CE control measures such as measures to control CE in dogs (e.g. killing dogs by guns or strychnine), they preferred and accepted the treatment of dogs. Private veterinarians and medical doctors thought nonviolent approaches to control CE in dogs was also more acceptable. ONSSA veterinarians said that it will be difficult to put it into practice.

Breeders declared that they never deworm their dogs. Moreover, even for rabies and despite their awareness about its danger for human health, they only vaccinate their dogs during free vaccination campaigns. They mentioned that they would totally refuse to buy an anthelmintic for a dog. For them, dog treatment was a waste of money.

Moderator (M): "Can you buy Praziquantel to treat your dogs?"
B6: "Absolutely not."
M: "Why?"
B4: "We can buy vaccines or medicines for our livestock, but not for dogs!"
B1: "We will not buy."
B10: "(shocked) Buy drugs for dogs!" (FGD/ Breeders/ Zaouiate Ait Isshak)

ONSSA veterinarians said they could administer the anthelmintic during dog vaccination campaigns against rabies. To answer the question if the ONSSA can implement the anthelmintic treatment of dogs twice per year, ONSSA vets said that such intervention needed a field mobilization, and unfortunately, ONSSA was suffering from the lack of staff. When the same question was asked during the FGD with the local authorities, they answered that a solution could be to give anthelmintic to people for treating their dogs. Breeders insisted that they would not give the drugs correctly to their dogs, because the majority would forget to give the drugs, and they would not make sure that the dogs have well swallowed the drug. ONSSA and private veterinarians said that even if they would distribute the anthelmintic for dogs to the families, they expected that breeders would not respect the instruction for drug administration, especially in rural areas where illiteracy was high and people did not care about dog treatment. ONSSA veterinarians suggested that the private veterinarians could do the anthelmintic treatment of dogs. According to private veterinarians, they would need to be subsidized for the implementation of this control measure.

"Private veterinarians can be the solution. They are in permanent contact with the breeders. They can treat dogs during their farm visits. However, we have to pay them." (IDI/ ONSSA veterinarian / Khenifra center)

3.2.3 Awareness raising campaign

All veterinarians (ONSSA and private), medical doctors and local authorities did converge on the idea that awareness remained the key of success for any control program. ONSSA vets mentioned that they conducted already several awareness raising campaigns and that the population was

therefore increasingly more aware about this zoonosis. They said being working in collaboration with the Ministry of Education and Ministry of Islamic Affairs. Breeders and women considered awareness raising campaigns important to control diseases, but that the current awareness raising campaigns needed to be changed. Women said that the current awareness campaigns were in Arabic or in French, and therefore could not be understood by a wide share of the Berber population. They also said that the awareness raising campaign must target each category of the population separately. Both breeders and women stated that they did not understand the posters, because they were complicated and written in classical Arabic or French, while they were illiterate. Women thought that a poster can only get the attention if it was designed in a simple way, with few sentences and more pictures.

> *Women (W)3: "Posters are in French or literary Arabic while we can barely understand dialectal Arabic."*
> *W5: "The posters must be understandable." (FGD/ Women/ M'rirt)*

ONSSA vets, doctors and local authorities thought that the current awareness strategy needed to be improved. According to them, the campaigns should invest in more means such as targeting the media and involving associations. Private veterinarians suggested participating in these campaigns, because they are in direct contact with the breeders: they claimed being available to organize sensitization meetings, inform breeders of the danger of zoonosis, and help the authorities to adapt the awareness campaign.

Breeders and women proposed to conduct sensitization campaigns via television in prime time. They proposed to conduct awareness campaigns in their mother tongue (Berber). Women proposed to raise awareness through associations and social networks.

> *"The assemblies like what you have done now is the best way to raise awareness, already after this rewarding discussion you will return home and you are sure and certain that we have well assimilated all the information and explanations that you have made about this disease." (FGD/ Women / Zaouiate Ait Isshak)*

During a FGD with women, they also proposed to raise children awareness at schools. These women said that their children were telling them about their school activities, and therefore,

children can be a source to share the message. On the contrary, messages through mosques were eventually presented as less prone to diffusion in the households.

> *W12: "If the teacher asks children to send a message to their parents, they will do it."*
>
> *W6: (laughs a little before speaking) "We ask our husband about what the imam said in the mosque; they answer us with a sentence or two but sometimes they refuse to answer us (women laughing), while my child tells me everything." (FGD/ Women/ El Kebab)*

The suggestion made by ONSSA veterinarians was to introduce courses on health education and good hygiene practices in student textbooks. Finally, medical doctors and ONSSA veterinarians proposed to design cartoons with messages on health education.

4 Discussion

In Morocco, a new strategy approach was proposed to control CE based on sheep vaccination, anthelmintic treatment of dogs, and awareness raising campaign. Theoretically, this strategy could control CE in 15 years (Torgerson, 2003). The use of qualitative research methodology allowed us to collect the perspectives of the affected population and of professionals from different structures responsible for the NHCP.

Human and animal health professionals recognized the persistence of CE in their region, despite the efforts made within the framework of the NHCP existing since 2007. Other Moroccan disease control programs such as the rabies and leishmaniosis ones are also failing to meet their objectives, representing important public health problems (Nassiri *et al.*, 2016; Direction de l'Epidémiologie et de Lutte contre les Maladies, 2018). This opens the discussion on the design of zoonosis control programs in the country in general, and the need to adapt these programs according to climatic, geographic and socio-cultural particularities for each region.

Firstly, we considered here that acceptability is a mechanism of appropriation. Appropriation consists in understanding, assimilating and sharing the results of the process and it is based on real participation of stakeholders in the construction of the ideas (Dechamp *et al.*, 2006). Alternatively, the study results showed that the level of acceptability regarding the new CE control measures was different among the population and the professionals. While human and animal health professionals

accepted this new strategy, breeders and their wives did not. This suggests different rationalities and issues within these two categories. First of all, breeders did not seem to perceive the indirect losses of CE, and secondly, they preferred investing in the fight against diseases for which they perceived direct effects. Considering their low economic level, they may perform a sort of cost / benefit calculation before choosing their preferential control strategy. As a privileged control action in public health, prevention is based on the assumption that adherence to a program depends on the degree of knowledge (World Health Organization, 2003; Guédéhoussou *et al.*, 2009). But other factors can lead a given person to join a given program, such as the symbolic representations of the drug, side effects, cost, etc as noted in a study on malaria control and the adherence of populations to a new therapeutic strategy (Le Hesran, 2009). In the Moroccan context, especially in rural areas, there is a poor understanding of the life cycle of CE (Thys *et al.*, 2019). However, even if animal and public health professionals expressed their acceptability in implementing the proposed control measures, a lack of involvement of the targeted populations could slow down, even become an obstacle to successfully implement the new CE control strategy. The veterinarians manifested some concerns about the effectiveness of these measures, especially about the EG95 vaccine, since it was a new approach they had never used. EG95 vaccine trials in other countries validated its effectiveness in controlling CE like in Austria and Argentina (Lightowlers *et al.*, 1999), and even in difficult and remote areas where only half of the lambs was vaccinated (Larrieu *et al.*, 2019). The results of such studies and field trials could serve to make the efficacy of this vaccine more convincing and engaging for veterinarians interviewed in this study. However, efficacy is not always a sufficient argument to trigger popular support (Le Hesran, 2009).

Concerning anthelmintic treatment of dogs, apart from the breeders, the large part of the participants accepted this approach of CE control. Breeders listed the lack of money to pay for the treatment, but also the foolishness and the lack of interest in dog treatments, as reasons for not going for dog treatment. Nevertheless, they preferred the treatment of dogs than killing them, especially if it was with the brutal and ineffective methods currently used to control dog population (RAPAD Maroc, 2016). This attitude reveals a kind of scale of values from which the person chooses his means of control. As the population preferred treating dogs with preventative measures instead of going towards brutal methods, this attitude should encourage them to adopt more easily the administration of anthelmintic treatment regarding CE control in dogs. It also calls out to the relationship with the dog and the category it fits in. Within the framework of our study, dogs can

be called "cash dogs" since they met the criteria of utility and were not a pet, object of human projection, as defined by the author of these typologies (Gouabault and Claudine Burton-Jeangros, 2010). The dog, a familiar element, is now confirmed, through the study itself, as a carrier of risk. The studied population was aware that this animal could transmit several disease. However, in preventive actions against zoonosis, where the dog is implicated as a host, the population expresses the opposition to the radical slaughter of dogs (Gouabault and Claudine Burton-Jeangros, 2010). The choices will therefore be oriented more favorably towards the sanitation of the living environment, the development of individual and collective hygiene after contact with dogs, correct conservation of food protected from all contamination related to dog faeces (Ménard, 2000). The dog is considered as a useful animal for humans. Anthropocentrism explains that human is generally interested in animals to derive a utility or an interest for his existence (Gouabault and Claudine Burton-Jeangros, 2010). This could explain that human spends money for an animal if he perceives benefit for him. In the case of CE, people did not treat dogs because they did not perceive the advantages for them to do it, but they were attached to their animals and refused the slaughter of dogs. This is why associations and population criticized the slaughter of dogs but their treatment and sterilization were well accepted, to the point that people were asking the associations for help to treat their dogs (RAPAD Maroc, 2016).

Awareness raising campaigns generally accompany health programs. Several ones were therefore carried out as part of the current NHCP, but they were criticized, either by the tools (posters), or by the language (classical Arabic or French) used for the dissemination of awareness messages. However, a well-informed person changes his practices (Vincent de Biasio, 2006). For Marcel Calvez, using the emblematic example of AIDS in public health, the social experience of people must be taken into account in any prevention policy (Vincent de Biasio, 2006). The social sciences give meaning to the notion of risk by producing knowledge about the behaviors likely to transmit diseases (Vincent de Biasio, 2006). In another study, it was noted that the CE life cycle was poorly understood in Morocco, also among health professionals (Thys *et al.*, 2019). It also revealed similarly to our study that the awareness raising campaign was not sufficient and was not adapted to the local population, allowing therefore the participant to express their needs and their experiences in order to propose a clear and feasible way for improvement that should inspire national strategies (31). Our study revealed also the significant barrier of the language used during awareness raising campaigns (French or classic Arabic) while illiteracy rate in Morocco is high

(HCP, 2018), and when, although the official language of Morocco is classical Arabic, there are five spoken national languages in practice: darija, hassani, tarifiyte, tamazighte and tachelhiyt (HCP, 2005). In addition to the language barrier, our study raised the fact that women were less informed than men. The awareness raising campaigns are more important during the feast of the sacrifice (each family sacrifices a sheep at home), and generally the awareness messages are transmitted in the mosques, while the mosques are frequented more by men than women. Moreover, the women said that their husbands did not convey to them what they heard in the mosques. Women's tasks in this studied area, such as treating water, washing hands, covering water jars, and adopting good hygiene practices are recognized as effective behaviors that reduce the burden of many diseases; therefore the lack of awareness among women remain major obstacles to improve their preventive hygiene practices (Sen, Östlin and George, 2007). CE is transmitted through the ingestion of food, or water contaminated by dog faeces, and the adoption of good hygiene practice is an important aspect for the control of this zoonosis. Participants proposed that such campaigns should better be disseminated in the local language (Berber), as a simple message (by pictures for example), and target each category of the population separately (women, children and men). The importance of health education for children was also emphasized, first as message transmitters to the whole family, and to protect them from infection. It was suggested to incorporate hygienic principles into student textbooks that underlines the role of children in school as a vector of "innovation" for their illiterate or almost illiterate parents. This was revealed in another study conducted in Morocco (Sidi Kacem), which proposed to replace words with pictures and integrate education against zoonosis in the school curriculum to change behavior in the long term (Ducrotoy *et al.*, 2015). The two suggestions reflect once again the exclusion of women, this time in terms of schooling. Indeed, 44% of Moroccans have never attended school and this rate is much higher among women (57.9% for women and 28.2% for men) (HCP, 2018). During this study, the women themselves proposed alternative means to overcome this exclusion by stressing the important role of associations in raising awareness through relationships of trust and simplicity. The creation of associations in Morocco has strong growth, more than 3,000 associations have joined the Rabat Call Dynamics (DAR) (La Commission Permanente chargée des Affaires Sociales et de la Solidarité, 2016). These associations can constitute a new source of dissemination of health and awareness messages. The expectation of a preventive, integrative and local strategy is therefore clearly expressed.

Before embarking on the tracks of implementing disease control strategies, a study of the expectations of the population is necessary. This is not only to reflect an ethical requirement specific to the bottom-up approach, but it is also a way to ensure a positive impact. The control of CE includes several actors. The implementation of the strategy must therefore take into account the needs and expectations, and the beliefs of each actor. It should be remembered that the behavior of populations in terms of health, such as the adoption of preventive measures, is often determined by prioritization carried out on all social needs (Vincent de Biasio, 2006). That is why we also studied the feasibility of the proposed strategy among different actors because understanding the emotional and material needs of each person category is the first pillar of the implementation of CE control strategy. Participants expressed several suggestions such as providing vaccination of sheep for free, conducting awareness campaigns to explain its benefits, incorporating EG95 vaccine with another vaccine widely used (like enterotoxaemia), and proving its effects by vaccinating pilot herds in different regions. Breeders expressed that they are more accepting of a treatment or a vaccine, if one of their neighbors had used it and they have seen the direct effects. For the anthelmintic treatment of dogs, they proposed to delegate it to the private vet. These recommendations drawn from this qualitative study, by both professionals and the target population, can well inform the strategy for controlling CE in the future in Morocco.

5 Conclusion

The qualitative approach of this study helped guide the new strategy to fight against CE, which for years has been a burden on human and animal health. The results obtained can help the implementation of a control strategy, while respecting the values of each key actor affected. Fears affect the accessibility of the control strategy, but the understanding of these factors and launching the dialogue with the different categories will help to find a place for successful control of CE, like other zoonosis or health programs. Our results can be projected on other regions of Morocco, and other countries, which share the same cultural and social ties.

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Discussion générale et Conclusions

Discussion générale

1 Une vue d'ensemble sur la méthodologie

Le Maroc est un pays fortement touché par l'hydatidose ou l'échinococcose kystique humaine et animale, malgré les efforts menés dans le cadre du programme national de lutte contre l'hydatidose (PNLH), lancé officiellement depuis 2007 (Mansouri *et al.*, 2015). Le but de ce travail est d'améliorer ce PNLH, en analysant les différentes facettes de cette zoonose, afin de l'adapter selon les considérations socio-économiques du pays.

Concernant l'approche à mener, nous avons été confrontés à une variété de choix entre les approches méthodologiques de la recherche quantitative et qualitative. L'approche qualitative explique la réalité des choses et l'approche quantitative explore le nombre de choses (Dumez, 2012). Dans cette étude, nous voulions développer des théories de moyenne portée imbriquées (Bouvier, 2008) pour expliquer la persistance de l'hydatidose au Maroc. L'objectif d'action était consubstantiel de la démarche de recherche, visant à instaurer une nouvelle stratégie de lutte. Par conséquent, l'approche qualitative et participative était la plus appropriée pour répondre à nos questions de recherche. Les études qualitatives ont un nombre déconcertant d'approches; cinq d'entre elles sont les plus utilisées dans la littérature sur les sciences de la santé, à savoir: la recherche narrative, la phénoménologie, la théorisation ancrée, l'ethnographie et les études de cas (Creswell, 2007). La recherche narrative explore les histoires de la vie d'un individu ; la phénoménologie décrit le partage d'expériences dans un phénomène ; la théorisation ancrée cherche à générer une théorie sur base d'observations de terrain sans théorie *a priori* ; l'ethnographie cherche à décrire et interpréter un groupe culturel entier; et les études de cas explorent les cas en collectant des informations de sources multiples (Creswell, 2007). Cette étude vise à construire une base théorique à partir des données collectées auprès des parties prenantes. On cherche non seulement à comprendre le phénomène, mais aussi à développer une théorie pour améliorer la stratégie de lutte contre l'hydatidose au Maroc. La théorisation ancrée semblait donc la plus appropriée. Cette approche favorise l'innovation grâce à une analyse approfondie des données de terrain (Corbin and Strauss, 1990). C'est un processus itératif, qui nécessite un aller-retour constant entre investigation et analyse (Guillemette, 2006). En parcourant plusieurs régions

du Maroc, la théorisation ancrée a été appliquée à travers plusieurs itérations de collecte de données. Grace à cette démarche, les résultats de notre approche étaient triples. Premièrement, nous avons complété la liste des causes de la persistance de l'hydatidose au Maroc, qui dépassent même cette seule zoonose et peuvent être appliquées aux autres zoonoses liées aux chiens et au contrôle sanitaire dans les abattoirs. Deuxièmement, des recommandations spécifiques sur le mode de fonctionnement des parties prenantes ont été formulées et présentées en tableau (voir l'étude sur l'analyse des parties prenantes). Celles-ci comprenaient la nécessité d'accroître la compréhension de la variété des perceptions des parties prenantes dans le PNLH et la nécessité d'intégrer toutes les parties prenantes identifiées dans cette étude. Finalement, des propositions théoriques ont été avancées pour une nouvelle stratégie de contrôle et confrontées au jugement des acteurs de terrain, où les résultats ont illustré la pertinence de la prise en compte des croyances socio-culturelles et de l'implication de la population locale.

Parmi les barrières rencontrées par les chercheurs qui adoptent les approches qualitatives, nous pouvons souligner la dominance symbolique des données quantitatives dans les recommandations aux décideurs politiques en matière de soins de santé, attribuant aux savoirs quantifiés une plus grande « valeur », donc un plus grand pouvoir de conviction pour motiver une décision (Nelson, 2008; Kohn and Christiaens, 2014). Pourtant, si les deux modalités de production de connaissance sont soumises à une même exigence de rigueur et un même besoin de prouver leur validité, l'approche qualitative est plus spécifiquement mise en doute à ce niveau du fait de l'importance du langage et de l'interprétation dans le processus, et plus généralement de la subjectivité du chercheur et des participants. A ce titre, elle requiert une vigilance toute particulière (Nelson, 2008). Le besoin d'asseoir cette validité de nos études nous est donc apparu central dans notre démarche, ayant recours à triangulation, la saturation, et jaugeant systématiquement nos approches selon les critères de Guba et Lincon 1985. Nous avons adopté une démarche neutre, où nous avons présenté les résultats du point de vue des participants dans leurs milieux de vie. Notre démarche répond à la définition du Creswell de la recherche qualitative : « *Les écrivains conviennent que l'on entreprend la recherche qualitative dans un cadre naturel où le chercheur est un instrument de collecte de données qui rassemble des mots ou des images, leur analyse inductive, met l'accent sur la signification de participants, et décrit un processus qui est expressif et convaincant dans le langage*» (Creswell, 1998).

Adopter la recherche qualitative nous a amené à surmonter plusieurs défis. D'abord la formulation des bonnes questions, choisir les sources de données (les observations, les entretiens individuels et groupes de discussion). Ainsi, la qualité de la recherche dépend de la richesse des données collectées et de l'obtention des explications les plus significatives sur les questions étudiées. Aussi, nous avons mené cette étude en réalisant les entretiens avec les gens dans leur milieu de vie, en installant un climat de confiance et de détente pour que nos participants puissent s'exprimer librement dans leur propre langue (arabe et berbère). Finalement, notre approche était itérative, étant retournés plusieurs fois sur le terrain pour la collecte des données à la suite d'analyses de premiers résultats.

Pour comprendre les différents aspects de l'hydatidose, nous avons donc adopté une approche quantitative pour estimer les différentes pertes économiques causées par ce parasite chez l'homme et chez l'animal, et une approche qualitative pour comprendre le processus du programme et les théories pour son amélioration. L'étude de l'impact économique de l'échinococcose kystique nous a permis de combiner les données quantitatives pour avoir des indications sur l'état de cette zoonose dans les différentes régions du Maroc. L'approche qualitative, pour étudier les obstacles et les enjeux auxquels le PNLH a fait face, et son approfondissement par l'analyse des parties prenantes, a permis d'appréhender les fondements organisationnels et de saisir les facteurs de changement de la mise en place de ce programme de lutte. La prise en compte d'opinions de personnes de statuts différents (les professionnels et la population locale) a rendu possible une meilleure compréhension des différentes facettes de la lutte contre l'hydatidose au Maroc. En outre, sur base d'une proposition de nouvelle stratégie de la lutte contre l'hydatidose/échinococcose, nous avons recueilli les observations des acteurs quant à sa possible mise en œuvre. Le recours à l'analyse thématique des entretiens a permis la combinaison de l'analyse de contenu et de certaines méthodes de description statistiques, dont le principal enjeu est de faciliter la synthèse et la présentation des données. Dès lors, cet usage ne doit pas faire perdre de vue l'orientation qualitative des études et l'absence d'objectif inférentiel. L'utilisation de l'outil informatique (le logiciel R) a permis de faciliter la procédure d'agrégation des données issues d'entretiens. Cet appui logiciel ne vient donc qu'en tant qu'outil de gestion des données et n'intervient pas dans le processus d'analyse lui-même. Ce dernier reste entièrement du ressort du chercheur posant les décisions de codage et d'interprétation des données codées agrégées.

En combinant les différentes sections de cette étude, nous avons pu appréhender la situation de l'hydatidose au Maroc par plusieurs points de vue différents, renvoyant à une sorte de processus général de triangulation sur l'ensemble de l'investigation. La triangulation consiste à mettre en œuvre des sources multiples de données, et une diversité de démarches afin de contribuer à l'amélioration de la fiabilité des résultats (Stavros and Westberg, 2009). La combinaison des quatre articles nous a permis de construire une vision plus globale de notre question de recherche par la combinaison de perspectives de recherche (Flick *et al.*, 2012). Chaque section endosse en effet une certaine perspective, s'appuyant sur une approche théorique particulière : approche économique, analyse des parties prenantes et approche participative.

Une diversité de perspectives est également recherchée au sein des études. Ainsi, l'étude de l'impact de l'hydatidose a elle-même mobilisé différentes méthodes au sein d'un même enjeu d'évaluation quantitative du fardeau : des méthodes financières (ou monétarisées), en estimant les pertes économiques directe et indirecte chez l'homme et l'animal, et des méthodes non financières, via le DALY et le zDALY. Ce dernier indicateur inclut en réalité un équivalent en « années de handicap » d'une perte en production animale initialement calculée comme financière. Si le calcul des pertes financières nécessite de « monétariser » des impacts de santé humaine, l'indicateur zDALY nécessite, quant à lui, de « dé-monétariser » des pertes économiques en les traduisant en pertes de bien-être humaines. Ensuite, l'analyse des obstacles et celle des parties prenantes donnent deux perspectives complémentaires sur la question des faiblesses organisationnelle du dispositif de lutte. À elles deux, ces études combinent l'observation, l'analyse qualitative inductive sans cadre théorique préexistant et la mobilisation d'un cadre théorique a priori pour la collecte et l'analyse de données qualitatives. Finalement, l'étude de la faisabilité et l'acceptabilité d'une nouvelle stratégie de lutte contre l'hydatidose/échinococcose a combiné également, dans une même approche inductive, les perspectives de professionnels et de la population cible sur l'acceptabilité sociale des mesures, que l'on pourrait catégoriser respectivement en perspectives externe et interne.

Parmi les craintes rencontrées lors de l'adoption de cette approche se trouve la subjectivité au moment de la collecte et/ou l'analyse des données. Le risque majeur est que le chercheur pourrait influencer les réponses de l'interviewé et/ou sélectionner, pendant la phase d'analyse de données, des éléments qui confirment ses propres idées et écarter des opinions (Kohn and Christiaens, 2014). Pour pallier ce problème, il faut collecter le maximum de variabilité de réponses et atteindre la saturation des réponses (Fusch and Ness, 2015a). Au-delà de ces éléments factuels tenant à la

démarche d'échantillonnage, le risque de subjectivité faisant dévier le chercheur d'une observation juste de la réalité appelle à une vigilance constante de sa part et à son intégration au sein d'une équipe. Ainsi l'intervention de plusieurs analystes permettra d'identifier les problèmes potentiels et d'accroître la pression critique sur la validité des données et interprétations. Partant de ces principes, nous avons organisé les focus groupes et les entretiens individuels jusqu'à la saturation. Comme l'étude était réalisée dans une région d'extension géographique limitée, nous avons interviewé presque tous les professionnels de santé humaine et animale des zones identifiées. Les interviews ont ciblé tous les vétérinaires de l'ONSSA, tous les techniciens vétérinaires qui travaillent dans les abattoirs, tous les vétérinaires privés de la région, tous les médecins chirurgiens de la région et les médecins chefs. Certes, en recherche qualitative, ce nombre d'entretiens n'est pas le facteur clé de sa validité ou de sa pertinence (Kohn and Christiaens, 2014), mais indique néanmoins le degré de couverture que cette étude a pu avoir de la question. L'analyse des parties prenantes, qui a précédé l'étude de la mise en place de la nouvelle stratégie de lutte contre l'hydatidose, nous a permis de sélectionner les acteurs (personnes ou organisations) qui sont susceptibles de fournir les informations les plus pertinentes. L'analyse des parties prenantes a donc joué ici un rôle de positionnement de la suite de l'investigation. Ayant identifié la cartographie des acteurs clés, nous avons recherché une forme de « représentativité » qualitative par une représentation des différentes perspectives, opinions et idées des différentes catégories de participants, sans pouvoir prétendre néanmoins couvrir l'étendue de la diversité interne à chacune de ces catégories.

2 L'hydatidose au Maroc

Le Maroc, comme d'autres pays en développement, est un pays où l'hydatidose humaine et animale présente une prévalence élevée (Aubry, 2013; Chebli *et al.*, 2017). Encore aujourd'hui, l'hydatidose est considérée comme une zoonose majeure négligée. Les dernières estimations de la prévalence de cette zoonose chez l'homme étaient de 1.9% (Chebli *et al.*, 2017). Concernant sa prévalence chez le bétail, elle était de 42,9% chez les bovins, 11,0% chez les ovins et 1,5% chez les caprins (I El Berbri *et al.*, 2015). Notre étude a révélé aussi la persistance et l'ampleur de cette zoonose dans les différents territoires du Maroc. En effet, les pertes monétaires atteignent jusqu'à 0.07% du PIB du pays.

Les indicateurs des fardeaux des maladies permettent de comparer la charge de morbidité entre les différentes maladies et entre les régions. La mesure de la charge de morbidité à l'échelle locale et nationale permet de prioriser les actions en matière de santé et d'environnement, de planifier l'action préventive, d'évaluer la performance des systèmes de santé, d'identifier les populations à haut risque, et d'établir des priorités dans la recherche en santé (WHO, 2021). Le DALY est souvent utilisé dans la comparaison du fardeau de différentes maladies puisqu'il prend en compte à la fois la mortalité et la morbidité. L'analyse des parties prenantes a révélé que le Ministère de la santé du Maroc ne considère pas la lutte contre l'hydatidose comme une priorité. Les grandes priorités du Ministère de la santé au Maroc sont les maladies des nouveau-nés, la santé de la mère et de l'enfant et le diabète (Ministère de la Santé, 2018). Le DALY pour les maladies néo-natales au Maroc a été estimé à 2598 années pour 100 000 personnes, à 733 années pour 100 000 personnes pour les anomalies congénitales et à 910 années pour 100 000 personnes pour le diabète sucré (OMS, 2015a). Comparé au DALY estimé pour l'hydatidose (0,5 année pour 100 000 personnes), ça peut expliquer, en partie, pourquoi cette zoonose est négligée au Maroc. Mais pour estimer le DALY pour l'hydatidose, seuls les cas opérés sont pris en considération, et même les cas dits asymptomatiques n'ont pas été considérés dans les estimations (où la prévalence a été estimé à 2%). D'où l'importance des autres composantes estimées, qui ont montré que lorsqu'on rajoute les pertes animales et les pertes de la productivité chez les cas asymptomatiques, l'impact de cette zoonose au Maroc apparaît comme plus important (environ 0,07% du PIB national).

L'estimation du DALY a révélé l'impact de l'hydatidose sur la qualité de vie mais elle ne prend pas en considération les cas asymptomatiques et les pertes animales surtout qu'on est devant une zoonose. Dans l'estimation du zDALY, l'ALE, qui reflète la morbidité et la mortalité animales, complète le DALY. Le zDALY apporte une réponse simple, pratique et rigoureuse pour calculer le fardeau sociétal des zoonoses (Torgerson *et al.*, 2018). Néanmoins, il ne prend pas en compte les cas asymptomatiques humains qui sont importants dans le cas de l'hydatidose. La conversion en DALY des pertes monétaires prend en compte ces cas asymptomatiques humains et animaux mais ne tient pas compte de l'impact sur la qualité de vie. C'est ainsi que l'image complète du fardeau potentiel de cette zoonose au Maroc est donnée par les différents indicateurs en complémentarité.

Durant les focus groupes et les entretiens individuels, la persistance et l'importance de cette zoonose ont été révélées plusieurs fois. Malgré le PNLH, l'hydatidose demeure une maladie sociale qui se propage principalement dans les communautés défavorisées et rurales. Des facteurs déterminants comme les conditions de vie, le mode d'alimentation, ou encore la qualité de l'habitat, qui influencent fortement l'entretien et l'évolution de la maladie, ne peuvent être contrôlés que par une approche globale de santé publique, à la fois multisectorielle et multidisciplinaire. Sans ce principe de solidarité multisectorielle, il est difficile aujourd'hui d'imaginer que l'on puisse éliminer l'hydatidose dans une société quelconque. L'analyse des parties prenantes a permis de comprendre comment les différents intervenants pouvaient influencer le PNLH. Cette analyse a permis de déceler des défaillances de fonctionnement au sein des parties prenantes, qui pourraient expliquer en partie les causes de la persistance de l'hydatidose au Maroc. Il a été rapporté que les causes de persistance de cette zoonose au Maroc sont multiples, y compris la mauvaise compréhension du cycle de vie du parasite par la population, l'infrastructure défectueuse des abattoirs et le nombre élevé des chiens errants, pour lesquels aucune stratégie n'a été définie (El Berbri *et al.*, 2015; Bardosh *et al.*, 2016; Thys *et al.*, 2019). L'analyse des parties prenantes a révélé d'autres facteurs, tenant à la difficulté du fonctionnement multisectoriel du programme. Dans un dispositif caractérisé par une grande variété des parties prenantes (santé publique et santé animale, politique et secteur privé, national et local), notre étude pointe vers un chevauchement de pouvoir et une faible implication des parties prenantes clés. La collaboration intersectorielle s'est avérée faible, tant dans l'analyse première des obstacles que dans l'analyse des parties prenantes. Ainsi, bien que l'intersectorialité soit bien caractérisée comme étant un enjeu crucial dans le contrôle des zoonoses (Marcotty *et al.*, 2013) et bien que les cadres de gestion du pays impliquent administrativement les secteurs requis et organisent théoriquement leurs interactions, les réalités de terrain mises à jour dans cette étude montrent que nombre de défis se situent encore bel et bien au niveau de cette coordination des pouvoirs et de la mise en concordance des priorités dans un objectif partagé.

Certes, l'étude des parties prenantes n'a pas proposé des solutions précises et clé-sur-porte pour améliorer la collaboration entre les différentes institutions. Cette démarche analytique n'est pas à concevoir comme procédure « diagnostique » débouchant sur un choix « thérapeutique » validé face aux déficiences observées. Sur le plan opérationnel, elle a néanmoins permis d'identifier des acteurs manquants dans la démarche de gestion, laquelle gagnera à les intégrer dans la formulation,

comme le dessine ensuite la dernière étude sur l'acceptabilité. Afin d'aller plus loin dans les recommandations pratiques, nous pourrions formuler les choses comme suit : il conviendrait d'aborder la question de la répartition des rôles et des pouvoirs, veiller à mettre en responsabilité les acteurs présentant le meilleur alignement de leurs priorités sur l'objectif du dispositif, et inspecter le cadre d'incitants qui permettrait de mieux aligner l'ensemble les priorités des acteurs clés, du niveau national au niveau local. Dans cette optique, il conviendrait de considérer des mécanismes coercitifs et collaboratifs, participant à la construction d'une confiance entre les acteurs du dispositif et de chaque acteur dans le dispositif. Si un accompagnement scientifique de cette évolution est souhaité, on comprend ici qu'il devra inclure des analyses des sciences sociales et politiques, ainsi qu'économiques (incitants et mécanismes collaboratifs), ouvrant un champ large d'investigations à visée opérationnelle.

Le PNLH est fondé sur trois grands axes principaux : l'interruption du cycle de vie du parasite, la prise en charge des patients porteurs de kyste hydatique, et la mise en place d'un arsenal législatif (Comité interministériel de lutte contre L'Hydatidose, 2007). L'étude a montré que l'implication de divers types d'acteurs avait finalement créé une série de chevauchements de responsabilité entre l'ONSSA et le BMH. L'étude a révélé que ce chevauchement concernant la gestion des abattoirs avait créé des tensions pour l'ensemble du personnel, ainsi que des frustrations et un évitement de responsabilité. La mise en œuvre des différentes mesures de lutte citées dans le programme venait ainsi s'ajouter à la liste des facteurs à l'origine de la démotivation du personnel de santé humaine et animale. Dans un cadre effectivement contraint en matière de ressources, cette démotivation semble davantage résulter des dysfonctionnements et conflits, d'un manque d'encadrement et de respect de la charge de travail individuelle, plutôt que du « manque de ressources » lui-même. Parmi les ressources manquantes, il est néanmoins utile de pointer vers les ressources humaines, qui appelleraient à une amélioration urgente de leur gestion. Le PNLH est donc traversé par les dysfonctionnements caractéristiques de l'infrastructure et du système de santé, et plus globalement des services publics. Loin donc d'être réformateur de ce système, le PNLH serait un révélateur de cette situation sanitaire critique. C'est la même situation qui est mise en évidence pour d'autres zoonoses comme la rage et la leishmaniose, qui persistent toujours sur le territoire marocain (Nassiri *et al.*, 2016; Direction de l'Epidémiologie et de Lutte contre les Maladies, 2018).

Au sein du PNLH, la déclaration obligatoire de l'hydatidose/échinococcose au niveau des abattoirs et des hôpitaux pourrait apparaître comme effectivement respectée (Chebli *et al.*, 2017). Néanmoins, la qualité de l'épidémio-surveillance à en attendre est à relativiser sur ses deux piliers. D'une part, au niveau hospitalier, seuls les cas opérés dans les hôpitaux publics sont déclarés, ce qui mène à une sous-estimation de la prévalence de cette zoonose au Maroc par omission des hôpitaux privés. Notons au passage que le personnel affecté à cette surveillance étant également insuffisant, n'ayant pas été remplacé suite aux départs à la retraite de ces dernières années, il n'est pas possible de se baser sur les chiffres officiels plus récents. Ensuite, au niveau des abattoirs, qui font face au même manque de personnel vétérinaire ou aux freins à la pratique indépendante de leur contrôle, la pratique massive de l'abattage à domicile empêche de toute façon ces abattoirs de jouer le rôle de point de contrôle attendu dans l'évaluation de la situation épidémiologique du pays.

L'analyse du PNLH a permis de bien comprendre les enjeux de sa mise en place, ainsi les interactions entre les différents intervenants directs et indirects. Cette analyse a révélé quatre problèmes spécifiques : i) le chevauchement de responsabilités entre les différentes structures, ii) le manque d'alignement entre responsabilités et priorités des acteurs, iii) une certaine inadéquation entre le programme et l'infrastructure marocaine actuelle, iv) la nécessité de mettre à jour les savoirs professionnels et d'inspecter les conditions dans lesquelles ils doivent être mis en œuvre. Au-delà de son rôle diagnostique ou analytique, cette étude ambitionne par ses approches participatives, appliquées aux niveaux nationaux et locaux, de promouvoir le nécessaire engagement entre les chercheurs et professionnels de santé humaine et animale pour rénover la stratégie de lutte.

3 Vers une nouvelle approche de lutte contre l'hydatidose

Cette recherche trouvait un cadre dans un projet proposant une nouvelle stratégie pour le contrôle de l'hydatidose/échinococcose, incluant la vaccination des ovins par le vaccin EG95. Les essais de la vaccination des moutons avec le vaccin EG95 ont montré que ce vaccin constitue un nouvel outil qui peut améliorer l'efficacité des stratégies de lutte contre l'hydatidose/échinococcose (Larrieu *et al.*, 2015). La vaccination des agneaux, associée au traitement anthelminthique des chiens, est une stratégie qui théoriquement pourrait contrôler cette zoonose en une période de 15 ans (Torgerson, 2003, 2006). Des essais de cette stratégie ont été réalisés au Moyen Atlas, et un des buts de cette thèse était d'étudier la mise en place de cette stratégie de lutte en ayant saisi les pourtours et

contraintes actuels du PLNH. Dans ce cadre, nous avons étudié l'acceptabilité et la faisabilité de cette nouvelle stratégie, dans les régions où les essais du vaccin et des traitements anthelminthiques des chiens ont été réalisés.

L'étude a été développé, de manière participative, selon les principes méthodologiques basés sur les résultats des groupes de discussion focalisée et des entretiens individuels. Les entretiens ont ciblé les responsables de la mise en place du programme actuel de la lutte contre l'hydatidose/échinococcose, ainsi que des vétérinaires privés et la population cible pour recueillir des opinions opérationnelles clairement définit. Les entretiens ont été réalisés avec des acteurs appartenant à des différentes entités, publiques, privées et la population cible. Cette étude représente à ce titre une première étape de ce que constituerait une démarche de reformulation du PLNH incluant toutes les parties prenantes. Une telle démarche participative donne de la visibilité aux rôles respectifs des acteurs et aide à l'anticipation (et si possible l'évitement) des difficultés à attendre lors de la mise en place de toute stratégie de lutte. Dans cette approche, tous les participants sont invités à s'approprier les enjeux de la lutte contre cette zoonose, jouant un double rôle de formulation et de pré-mobilisation.

Avant une adéquation opérationnelle, face au besoin de reformuler la stratégie générale, la méthodologie choisie présentait d'abord une adéquation scientifique, l'approche qualitative étant la plus appropriée pour répondre à nos questions de recherche. En effet, devant la question « comment mettre en place une nouvelle approche de lutte ? », l'approche participative dans une démarche de recherche qualitative visait à la compréhension fine des phénomènes étudiés, en présentant les acteurs avec leurs actions et interactions (Dumez, 2012; Kohn and Christiaens, 2014), identifiant leurs motivations et perceptions telles qu'ils peuvent les formuler individuellement ou collectivement. Il est intéressant ici d'identifier cette adéquation de méthode entre la visée analytique et opérationnelle, dans un cadre dès lors de recherche-action.

4 Recommandations

L'OMS a classé certaines maladies infectieuses et parasitaires, qui se rencontrent principalement dans les zones rurales ou dans les zones urbaines pauvres et marginalisées des pays à revenu faible et intermédiaire, dans la catégorie des "maladies tropicales négligées" (MTN) (WHO, 2020a). Parmi ces maladies, les zoonoses négligées ont un rôle de premier plan, en raison de leur double impact sur la santé publique, la production animale et les exportations de bétail, dont l'hydatidose

(OMS, 2015b). Leur gestion nécessite des approches intégrées multidisciplinaires (WHO, 2020a). Au Maroc, cette collaboration à l'interface animal-humain-environnement, comme le présente le concept "One Health", est actuellement défaillante (El Berbri *et al.*, 2020). L'approche « One Health » peut se définir comme étant la valeur ajoutée de la collaboration entre les secteurs de la santé humaine, animale et environnementale pour construire une unité solide, multidisciplinaire, pour le contrôle des maladies humaines et animales (Rock *et al.*, 2009; Zinsstag *et al.*, 2015). Notre étude a montré aussi à la fois l'importance de cette intégration, la valeur ajoutée qui peut en émerger et l'insuffisance de sa mise en œuvre au Maroc. L'importance de la collaboration entre les différentes parties prenantes a été révélé comme facteur déterminant à travers les différentes études de notre travail. Ainsi, la formulation d'un nouveau plan de contrôle de l'hydatidose pourrait elle-même inspirer et s'intégrer dans une réflexion plus large sur la mise en œuvre de l'approche One Health au Maroc. La création d'un comité de coordination One Health pourrait être imaginée, rassemblant au minimum des représentants des secteurs de la santé humaine, de la médecine vétérinaire et de l'environnement. Prenant en considération les besoins et les attentes de la population cible, ce comité pourrait élargir ses composantes à des représentations de la société civile, ainsi qu'aux instances en charge des questions de développement économique et humain, au niveau national et des territoires.

Plusieurs scénarios de lutte contre l'hydatidose sont possibles, se basant par exemple sur le traitement anthelminthique intensif des chiens et la diminution de la population canine, ou bien adoptant le vaccin ovin à combiner avec un traitement anthelminthique moins intensif des chiens (Torgerson, 2006). Mais chaque stratégie est confrontée à des défis et limites. L'utilisation du praziquantel présente plusieurs défis logistiques: un goût et une odeur que les chiens trouvent déplaisants, aucune assurance que chaque chien a ingéré la dose complète, difficulté à déterminer la dose correcte (le poids est estimé sur le terrain), la réticence des propriétaires de chiens à administrer les nombreuses pilules nécessaires à chaque vermifuge (Larrieu and Zanini, 2012). En ce qui concerne la vaccination des ovins, le défi majeur tient à la résistance des éleveurs qui ne reconnaissent pas l'impact de l'hydatidose sur leur troupeau, aux pâturages contaminés et aux ressources limitées (Larrieu and Zanini, 2012). Notre étude a proposé des solutions pour surmonter ces différents défis, en s'adressant à la population cible et aux structures responsables de la mise en place du PNLH, particulièrement les professionnels qui gèrent le PNLH sur le terrain. Les participants à cette étude ont élaboré ensemble des stratégies pour dépasser chaque défi, posant les

questions rencontrées sur le terrain et cherchant les possibilités de réunir leurs objectifs pour instaurer les premières étapes d'une approche One Health. Ils ont souligné que le vaccin doit être gratuit, incorporé avec celui visant l'entérotoxémie (qui est largement utilisé), impliquer davantage le secteur privé et l'importance de tenir compte du contexte socio-culturel dans la planification stratégique et la communication.

L'étude a souligné les difficultés de la gestion de la population canine qui est facteur déterminant de la lutte contre plusieurs zoonoses, lié à une complexité du statut du chien au Maroc. Généralement, il existe plusieurs catégories de chiens : chiens à propriétaires qui peuvent être enfermés ou laissés libres mais qui rentrent régulièrement au foyer; les chiens sans propriétaire mais vivant en contact étroit avec les communautés humaines; et les chiens sauvages (tableau 1) (Serpell, 1995). Au Maroc, 78,5% des chiens dans les zones rurales sont en liberté pour aller chercher de la nourriture et plus de 53% des naissances sont abandonnées par leurs propriétaires (Bouaddi et al., 2018). Ceci se traduit par une importante population de chiens errants, ayant ou n'ayant pas de propriétaires. Ces chiens errent au niveau des souks, des décharges publiques et au niveau des abattoirs, qui représentent une source importante de nourriture pour eux (Ouhelli *et al.*, 1981). Les chiens à propriétaires laissés libres mais qui rentrent au foyer constituent la source majeure des contaminations humaines de plusieurs zoonoses, plus particulièrement, la rage, la leishmaniose et l'hydatidose. Dès lors, les zoonoses transmises par les chiens présentant des facteurs de risque communs, une approche de lutte intégrée devrait être envisagée. Une telle approche devra tenir compte de la situation locale souvent complexe de ces chiens, dits « errants » de façon générale mais différant entre eux par leur liberté de mouvement et le régime de leur propriété (Tableau 1).

Tableau 1 : **les différentes catégories de chiens**

Catégorie	**Mode de vie**		
Chiens à propriétaires confinés	Chiens à propriétaires enfermés ou attachés	Chiens d'intérieur	vivant essentiellement à l'intérieur des habitations
		Chiens d'extérieur	de berger, de chasse ou de garde
Chiens à propriétaires fugueurs	Chiens échappés ou laissés libres mais qui rentrent régulièrement au foyer		
Chiens en vagabondage	Chiens sans propriétaire et sans foyer clairement identifiés mais vivant en contact étroit des communautés humaines et qui en dépendent pour se nourrir ; comme le vagabond ils peuvent se déplacer de village en village.		
Chiens féraux	Chiens nés à l'état sauvage, non sociabilisé à l'homme et craignant l'homme		

Vu les ressources financières limitées, évoquées largement par les parties prenantes, un séquençage et une priorisation des phases de lutte contre l'hydatidose au Maroc devront être pensés en intégrant ces parties prenantes à la décision. Par exemple, afin d'accélérer la lutte contre la mortalité maternelle et néonatale, le Togo, le Benin, le Sénégal et la Guinée, ont initié un processus de priorisation stratégique des structures sanitaires pour mettre en place un réseau de maternités, identifiant les défis de chaque phase, ce qui a permis d'améliorer l'accès aux soins (Moreira *et al.*, 2019). Une investigation dans ce sens pourra orienter la prise de décision concernant cette zoonose au Maroc.

Ce travail constitue une base méthodologique pour une meilleure prise de décision. À partir de ces résultats, la discussion de la nécessité de s'investir vers des nouvelles approches de lutte a été ouverte. Cette base ouvre d'autres questions et perspectives, qui devraient faire l'objet de suites directes afin de mieux informer la décision publique. Ainsi, il apparaît important de poursuivre une modélisation épidémiologique et économique des différentes approches de lutte, afin d'aboutir à une évaluation claire de la rentabilité et des bénéfices sociétaux à attendre de ce contrôle. Ces études seront bien entendu nourries des résultats du projet de recherche ayant abrité cette thèse, incluant outre le présent travail des tests de vaccination ovine et traitement anthelminthique des chiens en milieu réel. Ces deux pans socio-économiques et épidémiologiques du projet pourront ainsi contribuer à la mise à disposition des parties prenantes rassemblées un outil de décision solide reposant sur des faits probants.

Conclusion générale

L'hydatidose/échinococcose est une zoonose qui touche la population marocaine et demeure un vrai problème de santé publique et un problème économique dans un pays dont l'économie est basée sur l'agriculture et en particulier l'élevage. Cette étude a analysé la faiblesse de son programme national de lutte (PNLH), lancé depuis 2007. L'étude de l'impact économique a montré l'importance des pertes causées par cette zoonose, surtout les pertes inaperçues, dans toutes les régions du Maroc. L'étude de l'impact économique fournit un point d'appui aux décideurs pour qu'ils puissent prendre en compte le fardeau dû à cette zoonose dans les formulations de politique et planifie le financement de sa lutte au sein d'un ensemble d'enjeux nationaux. L'analyse du PNLH a révélé que celui-ci, tel qu'il est rédigé, n'a pas pris en considération l'infrastructure du pays et le niveau socio-culturel de la population locale, ni même la diversité complète des acteurs à impliquer. Des acteurs pourtant impliqués dans la mise en œuvre n'ont pas été pris en compte lors de la rédaction du programme, ce qui a créé des chevauchements de pouvoir et une évasion de responsabilité. Cette étude a envisagé l'acceptabilité d'une nouvelle stratégie de lutte contre l'hydatidose/échinococcose, basée sur la vaccination des ovins (le vaccin EG95) et le traitement anthelminthique des chiens. Le PNLH a été analysé par plusieurs approches, ainsi que la nouvelle stratégie proposée, c'est pour ces raisons, les résultats de cette étude sont importants à prendre en compte pour la mise en place d'un plan de lutte contre l'hydatidose/échinococcose plus adaptée. L'étude a mis en évidence que les parties prenantes doivent prendre l'habitude d'établir un dialogue cohérent et régulier, et améliorer leurs réseaux relationnels, dans le but d'une meilleure collaboration intra et interinstitutionnelle. Loin d'être négligée, la prise en compte des croyances socio-culturelles de la population locale est une des composantes essentielles d'une nouvelle stratégie de lutte contre l'hydatidose/échinococcose et toute autre zoonose.

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Communications

Communications orales

- **Saadi A.** Amrir F. Rhalem A. Fillali H, Thys S. Kirschvink N. Marcotty T. Oukessou M. Sahibi H and Antoine-Moussiaux N. Added Value of Social Sciences in setting up a Control Program against Hydatidosis in Morocco. XXVII world congress on echinococcosis. Alger 2017
- **Saadi A**., Amarir F., Rhalem A. Filali H. , Thys S., Kirschvink N. ,Marcotty T., Bouslikhane M., Oukessou M. , Sahibi H., and Antoine-Moussiaux N. Situation of Cystic echinococcosis and main cause of its persistence in Khénifra, Morocco. PhD student day. Liège 2018
- Amarir Fatima Ezzahra, **Saadi Aouatif**, Rhalem Abdelkebir, Sahibi Hamid, Kirschvink Nathalie. Bouslikhane Mohammed, Marcotty Tanguy and Antoine-Moussiaux Nicolas. Cystic echinococcosis in Morocco: Prevalence in humans and dogs in Khenifra province. XXVII world congress on echinococcosis. Alger 2017
- Amarir Fatima Ezzahra, **Saadi Aouatif**, Rhalem Abdelkebir, Sahibi Hamid, Kirschvink Nathalie. Bouslikhane Mohammed, Marcotty Tanguy and Antoine-Moussiaux Nicolas. Cystic echinococcosis in Morocco: Prevalence of cystic echinococcosis and cyst fertility in ruminants in the Mid-Atlas region of Morocco. XXVII world congress on echinococcosis. Alger 2017

Posters

- **Saadi A**. Amrir F. Rhalem A. Fillali H, Thys S. Kirschvink N. Marcotty T. Oukessou M. Sahibi H and Antoine-Moussiaux N. Use of « Stakeholder Mapping » to evaluate and improve the National Program of Hydatidosis Control in Morocco. XXVII world congress on echinococcosis. Alger 2017
- **Saadi A**. Amrir F. Rhalem A. Fillali H, Thys S. Kirschvink N. Marcotty T. Oukessou M. Sahibi H and Antoine-Moussiaux N. Importance of qualitative approaches to adapt control strategy of cystic echinococcosis according to conditions of an endemic region in Morocco. Congrès ISESSAH. Montpellier 2018
- **Saadi A**. Amrir F. Rhalem A. Fillali H, Thys S. Kirschvink N. Marcotty T. Oukessou M. Sahibi H and Antoine-Moussiaux N. Added Value of Social Sciences in Assessing Social and Economic Impact of Cystic Echinococcosis in Camels. 5th conference of ISOCARD (ISOCARD-2018), à Laayoune 2018.

- Amarir Fatima Ezzahra, **Saadi Aouatif**, Rhalem Abdelkebir, Sahibi Hamid, Kirschvink Nathalie. Bouslikhane Mohammed, Marcotty Tanguy and Antoine-Moussiaux Nicolas. Comparative studies of prevalence of the hydatid cysts, as well as viability and fertility of the protoscoleces depending on the location of different organs in ruminants in the Middle Atlas region of Morocco. Séminaire du pôle d'infectiologie NARILIS. Namur

Prix obtenus

- Prix de meilleur communication scientifique au « XXVII world congress on echinococcosis ». Alger 2017.
- Prix du meilleur Posters scientifique au Congrès ISESSAH. Montpellier 2018

Annexes

Annexe I

Supporting information 1: Parameters used to estimate organ losses in slaughterhouses

Year	Region	Species	Lung condemned (Kg)	Lungs price (Dh) (Min)	lungs price (Dh) (Max)	Liver condemned (Kg)	liver price Dh) (Min)	liver price (Dh) (Max)	Prevalence of CE
2011	CODA	Ovine	3754	25	30	2104	70	100	3,27%
2011	GC	Ovine	1733	25	30	972	70	100	2,46%
2011	LBSGE	Ovine	5608	25	30	3143	70	100	8,76%
2011	MTATA	Ovine	6004	25	30	3366	70	100	8,78%
2011	MT	Ovine	4326	25	30	2425	70	100	24,95%
2011	Or	Ovine	1503	25	30	842	70	100	2,89%
2011	RSZCB	Ovine	1156	25	30	648	70	100	1,86%
2011	SM	Ovine	1631	25	30	915	70	100	6,90%
2011	TT	Ovine	2536	25	30	1422	70	100	8,79%
2011	THTFB	Ovine	1006	25	30	564	70	100	15,19%
2012	CODA	Ovine	3355	25	30	1880	70	100	4,61%
2012	GC	Ovine	2968	25	30	1664	70	100	2,13%
2012	LBSGE	Ovine	8725	25	30	4891	70	100	10,96%
2012	MTATA	Ovine	5531	25	30	3100	70	100	8,36%
2012	MT	Ovine	9583	25	30	5372	70	100	21,05%
2012	Or	Ovine	9542	25	30	5348	70	100	3,03%
2012	RSZCB	Ovine	10441	25	30	5852	70	100	2,35%
2012	SM	Ovine	4337	25	30	2431	70	100	6,86%
2012	TT	Ovine	11311	25	30	6340	70	100	10,07%
2012	THTFB	Ovine	9268	25	30	5195	70	100	13,05%
2013	CODA	Ovine	4855	25	30	2721	70	100	4,15%
2013	GC	Ovine	1878	25	30	1052	70	100	1,25%
2013	LBSGE	Ovine	4015	25	30	2251	70	100	13,55%
2013	MTATA	Ovine	2546	25	30	1427	70	100	7,00%
2013	MT	Ovine	2752	25	30	1542	70	100	20,38%
2013	Or	Ovine	1947	25	30	1092	70	100	2,29%
2013	RSZCB	Ovine	4375	25	30	2452	70	100	2,30%
2013	SM	Ovine	5540	25	30	3106	70	100	6,59%
2013	TT	Ovine	4108	25	30	2302	70	100	13,81%
2013	THTFB	Ovine	1606	25	30	901	70	100	16,35%
2014	CODA	Ovine	3276	25	30	1837	70	100	4,31%
2014	GC	Ovine	2815	25	30	1578	70	100	1,16%
2014	LBSGE	Ovine	3524	25	30	1975	70	100	15,61%
2014	MTATA	Ovine	1867	25	30	1046	70	100	8,11%

2014	MT	Ovine	3795	25	30	2128	70	100	12,47%
2014	Or	Ovine	3494	25	30	1959	70	100	2,04%
2014	RSZCB	Ovine	6230	25	30	3492	70	100	2,10%
2014	SM	Ovine	2864	25	30	1606	70	100	7,13%
2014	TT	Ovine	5310	25	30	2976	70	100	16,00%
2014	THTFB	Ovine	5298	25	30	2970	70	100	15,52%
2011	CODA	Cattle	8237	25	30	5165	70	100	9,71%
2011	GC	Cattle	3822	25	30	2396	70	100	13,29%
2011	LBSGE	Cattle	14332	25	30	8988	70	100	17,42%
2011	MTATA	Cattle	17469	25	30	10955	70	100	11,33%
2011	MT	Cattle	24629	25	30	15445	70	100	25,81%
2011	Or	Cattle	10143	25	30	6360	70	100	8,16%
2011	RSZCB	Cattle	14839	25	30	9305	70	100	5,24%
2011	SM	Cattle	30640	25	30	19214	70	100	15,61%
2011	TT	Cattle	2514	25	30	1576	70	100	10,68%
2011	THTFB	Cattle	1664	25	30	1044	70	100	21,14%
2012	CODA	Cattle	3347	25	30	2099	70	100	6,17%
2012	GC	Cattle	5841	25	30	3663	70	100	8,42%
2012	LBSGE	Cattle	8725	25	30	5472	70	100	19,91%
2012	MTATA	Cattle	7616	25	30	4775	70	100	10,50%
2012	MT	Cattle	20917	25	30	13117	70	100	28,28%
2012	Or	Cattle	21620	25	30	13557	70	100	6,53%
2012	RSZCB	Cattle	13392	25	30	8398	70	100	6,96%
2012	SM	Cattle	6341	25	30	3976	70	100	11,22%
2012	TT	Cattle	23553	25	30	14770	70	100	12,87%
2012	THTFB	Cattle	26275	25	30	16477	70	100	15,19%
2013	CODA	Cattle	3928	25	30	2463	70	100	5,69%
2013	GC	Cattle	1375	25	30	862	70	100	7,50%
2013	LBSGE	Cattle	3617	25	30	2268	70	100	25,65%
2013	MTATA	Cattle	3492	25	30	2190	70	100	9,27%
2013	MT	Cattle	15077	25	30	9455	70	100	29,66%
2013	Or	Cattle	8266	25	30	5183	70	100	4,69%
2013	RSZCB	Cattle	19503	25	30	12230	70	100	6,15%
2013	SM	Cattle	23204	25	30	14550	70	100	10,04%
2013	TT	Cattle	14328	25	30	8985	70	100	15,06%
2013	THTFB	Cattle	5474	25	30	3433	70	100	17,21%
2014	CODA	Cattle	14463	25	30	9070	70	100	5,85%
2014	GC	Cattle	17130	25	30	10742	70	100	8,50%
2014	LBSGE	Cattle	9103	25	30	5709	70	100	31,55%
2014	MTATA	Cattle	4354	25	30	2731	70	100	2,29%
2014	MT	Cattle	12257	25	30	7686	70	100	21,04%

2014	Or	Cattle	11712	25	30	7344	70	100	4,28%
2014	RSZCB	Cattle	13944	25	30	8744	70	100	5,72%
2014	SM	Cattle	5765	25	30	3615	70	100	8,98%
2014	TT	Cattle	19317	25	30	12113	70	100	14,51%
2014	THTFB	Cattle	20762	25	30	13019	70	100	14,64%
2011	CODA	Goat	273	25	30	136	70	100	1,64%
2011	GC	Goat	47	25	30	23	70	100	2,40%
2011	LBSGE	Goat	407	25	30	203	70	100	1,70%
2011	MTATA	Goat	543	25	30	271	70	100	4,85%
2011	MT	Goat	9	25	30	4	70	100	12,70%
2011	Or	Goat	39	25	30	20	70	100	1,92%
2011	RSZCB	Goat	9	25	30	5	70	100	1,58%
2011	SM	Goat	43	25	30	22	70	100	1,76%
2011	TT	Goat	1279	25	30	639	70	100	6,03%
2011	THTFB	Goat	1065	25	30	532	70	100	8,73%
2012	CODA	Goat	2917	25	30	1458	70	100	0,51%
2012	GC	Goat	4031	25	30	2015	70	100	3,56%
2012	LBSGE	Goat	2286	25	30	1143	70	100	4,03%
2012	MTATA	Goat	853	25	30	426	70	100	3,23%
2012	MT	Goat	2705	25	30	1352	70	100	10,62%
2012	Or	Goat	2638	25	30	1319	70	100	2,52%
2012	RSZCB	Goat	3298	25	30	1648	70	100	1,58%
2012	SM	Goat	583	25	30	291	70	100	1,92%
2012	TT	Goat	3766	25	30	1883	70	100	6,69%
2012	THTFB	Goat	2618	25	30	1309	70	100	7,07%
2013	CODA	Goat	844	25	30	422	70	100	0,88%
2013	GC	Goat	489	25	30	244	70	100	1,79%
2013	LBSGE	Goat	1088	25	30	544	70	100	6,19%
2013	MTATA	Goat	801	25	30	400	70	100	4,16%
2013	MT	Goat	485	25	30	242	70	100	12,85%
2013	Or	Goat	295	25	30	147	70	100	2,15%
2013	RSZCB	Goat	784	25	30	392	70	100	1,57%
2013	SM	Goat	992	25	30	496	70	100	1,23%
2013	TT	Goat	3142	25	30	1571	70	100	5,85%
2013	THTFB	Goat	1600	25	30	800	70	100	8,60%
2014	CODA	Goat	1988	25	30	994	70	100	1,56%
2014	GC	Goat	1390	25	30	695	70	100	2,34%
2014	LBSGE	Goat	1552	25	30	776	70	100	9,10%
2014	MTATA	Goat	698	25	30	349	70	100	5,97%
2014	MT	Goat	1448	25	30	724	70	100	8,15%
2014	Or	Goat	1325	25	30	663	70	100	2,20%

2014	RSZCB	Goat	1665	25	30	832	70	100	1,47%
2014	SM	Goat	623	25	30	311	70	100	1,02%
2014	TT	Goat	1366	25	30	683	70	100	7,34%
2014	THTFB	Goat	1403	25	30	701	70	100	8,09%
2011	CODA	Camel	0	25	30	0	70	100	0%
2011	GC	Camel	6	25	30	2	70	100	80,00%
2011	LBSGE	Camel	3431	25	30	1025	70	100	9,82%
2011	MTATA	Camel	22	25	30	6	70	100	4,02%
2011	MT	Camel	1	25	30	0	70	100	2,17%
2011	Or	Camel	0	25	30	0	70	100	0%
2011	RSZCB	Camel	30	25	30	9	70	100	2,05%
2011	SM	Camel	118	25	30	35	70	100	6,55%
2011	TT	Camel	0	25	30	0	70	100	0%
2011	THTFB	Camel	56	25	30	17	70	100	36,23%
2012	CODA	Camel	0	25	30	0	70	100	0%
2012	GC	Camel	0	25	30	0	70	100	8,42%
2012	LBSGE	Camel	3308	25	30	988	70	100	25,03%
2012	MTATA	Camel	8	25	30	3	70	100	5,90%
2012	MT	Camel	5	25	30	1	70	100	3,08%
2012	Or	Camel	0	25	30	0	70	100	0,38%
2012	RSZCB	Camel	42	25	30	13	70	100	5,03%
2012	SM	Camel	49	25	30	15	70	100	4,24%
2012	TT	Camel	0	25	30	0	70	100	0,00%
2012	THTFB	Camel	20	25	30	6	70	100	20,75%
2013	CODA	Camel	0	25	30	0	70	100	0%
2013	GC	Camel	0	25	30	0	70	100	0%
2013	LBSGE	Camel	5874	25	30	1754	70	100	28,82%
2013	MTATA	Camel	15	25	30	5	70	100	4,80%
2013	MT	Camel	0	25	30	0	70	100	0%
2013	Or	Camel	59	25	30	17	70	100	5,95%
2013	RSZCB	Camel	39	25	30	12	70	100	2,84%
2013	SM	Camel	42	25	30	12	70	100	2,05%
2013	TT	Camel	0	25	30	0	70	100	0%
2013	THTFB	Camel	16	25	30	5	70	100	2,94%
2014	CODA	Camel	28	25	30	9	70	100	4,99%
2014	GC	Camel	0	25	30	0	70	100	0%
2014	LBSGE	Camel	4069	25	30	1216	70	100	23,49%
2014	MTATA	Camel	329	25	30	98	70	100	27,98%
2014	MT	Camel	0	25	30	0	70	100	0%
2014	Or	Camel	0	25	30	0	70	100	0%
2014	RSZCB	Camel	55	25	30	17	70	100	4%

2014	SM	Camel	12	25	30	4	70	100	0,68%
2014	TT	Camel	0	25	30	0	70	100	0%
2014	THTFB	Camel	17	25	30	5	70	100	7,81%

Annexe II

Supporting information 2: Costs of CE in humans

Expense items		Cost per patient (USD)
Medical fees		
Consultations		111
Medical imaging		111
Pharmaceuticals		97
Laboratory analysis		97
Cost of surgery		720
Postoperative treatment		138
Total medical expenses		**1274**
Non-medical expenses		
Family visit		222
Transport and accommodation		166
Extra hospital food		138
Total non-medical expenses		**526**
Indirect costs		
Cost of invalidity of patients before surgery		415
Cost of invalidity of patients after surgery		1108
Work stoppage of a family member		138
Total indirect costs		**1800**
Basic cost		**3600**
Risk of minor complications 11%		388
Risk of serious complications 6%		222
Risk of recurrence 2%		83
Total cost		**4292**

Annexe III

Supporting information 3 Population of Morocco according to the 2014 census (HCP)

Region	Households	Population
Tanger – Tetouan – Al Hoceima	799124	3556729
Oriental	494530	2314346
Fès - Meknès	919497	4236892
Rabat – Salé -Kénitra	1015107	4580866
Beni Mellal – Khenifra	520174	2520776
Grand Casablanca – Settat	1559404	6861739
Marrakech - Safi	928120	4520569
Drâa - Tafilalet	277998	1635008
Souss-Massa	601511	2676847
Guelmim – Oued Noun	90202	433757
Laayoune – Sakia El Hamra	78754	367758
Eddakhla – Oued Eddahab	29385	142955

Annexe IV

Supporting information 4: CE Surgical incidence in the different region of Morocco

	2011	2012	2013	2014
O.Eddahab Lagouira	1	1	0	0
Laayoune Sakia Lhamra Boujdour	13	2	5	1
Guelmim Es Semara	9	10	11	10
Souss Massa Draa	90	75	69	75
Gharb Chrarda Bni Hssen	97	73	73	37
Chaouia Ouardigha	150	70	38	35
Marrakech Tansifet Al Haouz	173	101	86	106
Région de l'Oriental	81	55	42	38
Rabat Salé Zemmour Zaer	126	115	93	77
Doukkala Abda	141	85	65	70
Tadla Azilal	58	41	30	37
Meknès Tafilalet	183	166	159	119
Fès Boulemane	97	47	53	45
Taza Al Hoceima Taounate	78	33	75	30
Grand Casablanca	63	121	123	5
Tanger Tétouan	106	87	46	39

Annexe V

Supporting information 5: Parameters used to estimate productivity losses in livestock

Year	Region	Species	Average milk per cow (Kg)	Price 1 liter of milk (dh) Min-Max	Slaughtered animals affected	Weight by carcass (kg)	Meat price (Dh) Min-Max	Female reproductive	Price of newborn (dh) Min-Max	Production of wood by animal (kg)	Price of 1kg wool (dh) Min-Max
2011	CODA	Ovine	-	-	7678	65	50-70	671172	300-700	2.6	1.5-2-2
2011	GC	Ovine	-	-	7056	65	50-70	1248357	300-700	2.6	1.5-2
2011	LBSGE	Ovine	-	-	4645	65	50-70	79719	300-700	2.6	1.5-2
2011	MTATA	Ovine	-	-	41009	65	50-70	1542221	300-700	2.6	1.5-2
2011	MT	Ovine	-	-	23982	65	50-70	1236655	300-700	2.6	1.5-2
2011	Or	Ovine	-	-	11774	65	50-70	1050307	300-700	2.6	1.5-2
2011	RSZCB	Ovine	-	-	4271	65	50-70	847036	300-700	2.6	1.5-2
2011	SM	Ovine	-	-	10655	65	50-70	451354	300-700	2.6	1.5-2
2011	TT	Ovine	-	-	8280	65	50-70	477050	300-700	2.6	1.5-2
2011	THTFB	Ovine	-	-	25234	65	50-70	1429466	300-700	2.6	1.5-2
2012	CODA	Ovine	-	-	11444	59	50-70	687244	300-700	2.6	1.5-2
2012	GC	Ovine	-	-	4347	59	50-70	1264948	300-700	2.6	1.5-2
2012	LBSGE	Ovine	-	-	5509	59	50-70	100114	300-700	2.6	1.5-2
2012	MTATA	Ovine	-	-	41218	59	50-70	1595322	300-700	2.6	1.5-2
2012	MT	Ovine	-	-	21133	59	50-70	1182093	300-700	2.6	1.5-2
2012	Or	Ovine	-	-	13646	59	50-70	1165972	300-700	2.6	1.5-2
2012	RSZCB	Ovine	-	-	7707	59	50-70	802747	300-700	2.6	1.5-2
2012	SM	Ovine	-	-	9112	59	50-70	560883	300-700	2.6	1.5-2
2012	TT	Ovine	-	-	8940	59	50-70	476818	300-700	2.6	1.5-2
2012	THTFB	Ovine	-	-	17049	59	50-70	1374431	300-700	2.6	1.5-2
2013	CODA	Ovine	-	-	9387	58	50-70	692535	300-700	2.6	1.5-2
2013	GC	Ovine	-	-	1794	58	50-70	1222737	300-700	2.5	1.5-2
2013	LBSGE	Ovine	-	-	6889	58	50-70	111131	300-700	2.5	1.5-2
2013	MTATA	Ovine	-	-	37165	58	50-70	1551490	300-700	2.6	1.5-2
2013	MT	Ovine	-	-	22372	58	50-70	1213172	300-700	2.5	1.5-2
2013	Or	Ovine	-	-	9698	58	50-70	1267997	300-700	2.7	1.5-2
2013	RSZCB	Ovine	-	-	5407	58	50-70	757769	300-700	2.6	1.5-2
2013	SM	Ovine	-	-	8319	58	50-70	574366	300-700	2.6	1.5-2
2013	TT	Ovine	-	-	11634	58	50-70	513114	300-700	2.6	1.5-2
2013	THTFB	Ovine	-	-	21519	58	50-70	1356735	300-700	2.7	1.5-2
2014	CODA	Ovine	-	-	9260	68	50-70	641124	300-700	2.6	1.5-2

2014	GC	Ovine	-	-	2919	68	50-70	1178771	300-700	2.7	1.5-2
2014	LBSGE	Ovine	-	-	7880	68	50-70	117785	300-700	2.7	1.5-2
2014	MTATA	Ovine	-	-	33797	68	50-70	1623021	300-700	2.6	1.5-2
2014	MT	Ovine	-	-	16722	68	50-70	1134411	300-700	2.7	1.5-2
2014	Or	Ovine	-	-	6346	68	50-70	1199702	300-700	2.5	1.5-2
2014	RSZCB	Ovine	-	-	6371	68	50-70	766487	300-700	2.6	1.5-2
2014	SM	Ovine	-	-	7377	68	50-70	568560	300-700	2.6	1.5-2
2014	TT	Ovine	-	-	11829	68	50-70	511141	300-700	2.7	1.5-2
2014	THTFB	Ovine	-	-	18406	68	50-70	1401359	300-700	2.6	1.5-2
2011	CODA	Cattle	1802	3.4-4.8	9208	314	50-70	145187	1500-3000	-	-
2011	GC	Cattle	1802	3.4-4.8	12738	314	50-70	48619	1500-3000	-	-
2011	LBSGE	Cattle	1802	3.4-4.8	1110	314	50-70	144479	1500-3000	-	-
2011	MTATA	Cattle	1802	3.4-4.8	14661	314	50-70	221448	1500-3000	-	-
2011	MT	Cattle	1802	3.4-4.8	6537	314	50-70	619	1500-3000	-	-
2011	Or	Cattle	1802	3.4-4.8	2601	314	50-70	198984	1500-3000	-	-
2011	RSZCB	Cattle	1802	3.4-4.8	5107	314	50-70	33820	1500-3000	-	-
2011	SM	Cattle	1802	3.4-4.8	10342	314	50-70	200913	1500-3000	-	-
2011	TT	Cattle	1802	3.4-4.8	3880	314	50-70	86640	1500-3000	-	-
2011	THTFB	Cattle	1802	3.4-4.8	13781	314	50-70	196794	1500-3000	-	-
2012	CODA	Cattle	2008	3.4-4.8	7243	335	50-70	158042	1500-3000	-	-
2012	GC	Cattle	2008	3.4-4.8	7341	335	50-70	46212	1500-3000	-	-
2012	LBSGE	Cattle	2008	3.4-4.8	1751	335	50-70	141914	1500-3000	-	-
2012	MTATA	Cattle	2008	3.4-4.8	14511	335	50-70	235227	1500-3000	-	-
2012	MT	Cattle	2008	3.4-4.8	7972	335	50-70	810	1500-3000	-	-
2012	Or	Cattle	2008	3.4-4.8	2638	335	50-70	197006	1500-3000	-	-
2012	RSZCB	Cattle	2008	3.4-4.8	6380	335	50-70	32210	1500-3000	-	-
2012	SM	Cattle	2008	3.4-4.8	8725	335	50-70	196653	1500-3000	-	-
2012	TT	Cattle	2008	3.4-4.8	4926	335	50-70	89308	1500-3000	-	-
2012	THTFB	Cattle	2008	3.4-4.8	8554	335	50-70	200873	1500-3000	-	-
2013	CODA	Cattle	1879	3.4-4.8	8623	317	50-70	167681	1500-3000	-	-
2013	GC	Cattle	1879	3.4-4.8	4793	317	50-70	46300	1500-3000	-	-
2013	LBSGE	Cattle	1879	3.4-4.8	2383	317	50-70	148640	1500-3000	-	-
2013	MTATA	Cattle	1879	3.4-4.8	16280	317	50-70	234051	1500-3000	-	-

2013	MT	Cattle	1879	3.4-4.8	14152	317	50-70	789	1500-3000	-	-
2013	Or	Cattle	1879	3.4-4.8	2234	317	50-70	173832	1500-3000	-	-
2013	RSZCB	Cattle	1879	3.4-4.8	6119	317	50-70	32946	1500-3000	-	-
2013	SM	Cattle	1879	3.4-4.8	8800	317	50-70	201056	1500-3000	-	-
2013	TT	Cattle	1879	3.4-4.8	6644	317	50-70	89071	1500-3000	-	-
2013	THTFB	Cattle	1879	3.4-4.8	13510	317	50-70	187711	1500-3000	-	-
2014	CODA	Cattle	2103	3.4-4.8	10032	272	50-70	149401	1500-3000	-	-
2014	GC	Cattle	2103	3.4-4.8	10114	272	50-70	43369	1500-3000	-	-
2014	LBSGE	Cattle	2103	3.4-4.8	3948	272	50-70	144348	1500-3000	-	-
2014	MTATA	Cattle	2103	3.4-4.8	16117	272	50-70	242990	1500-3000	-	-
2014	MT	Cattle	2103	3.4-4.8	13449	272	50-70	683	1500-3000	-	-
2014	Or	Cattle	2103	3.4-4.8	2009	272	50-70	192028	1500-3000	-	-
2014	RSZCB	Cattle	2103	3.4-4.8	7877	272	50-70	33819	1500-3000	-	-
2014	SM	Cattle	2103	3.4-4.8	8994	272	50-70	207159	1500-3000	-	-
2014	TT	Cattle	2103	3.4-4.8	6307	272	50-70	91577	1500-3000	-	-
2014	THTFB	Cattle	2103	3.4-4.8	11604	272	50-70	189156	1500-3000	-	-
2011	CODA	Goat	-	-	919	18	50-70	403294	250-500	-	-
2011	GC	Goat	-	-	50	18	50-70	411715	250-500	-	-
2011	LBSGE	Goat	-	-	3582	18	50-70	345911	250-500	-	-
2011	MTATA	Goat	-	-	14013	18	50-70	22468	250-500	-	-
2011	MT	Goat	-	-	8670	18	50-70	91292	250-500	-	-
2011	Or	Goat	-	-	2584	18	50-70	500422	250-500	-	-
2011	RSZCB	Goat	-	-	817	18	50-70	146304	250-500	-	-
2011	SM	Goat	-	-	7897	18	50-70	94068	250-500	-	-
2011	TT	Goat	-	-	3981	18	50-70	418812	250-500	-	-
2011	THTFB	Goat	-	-	7567	18	50-70	447484	250-500	-	-
2012	CODA	Goat	-	-	253	24	50-70	437072	250-500	-	-
2012	GC	Goat	-	-	205	24	50-70	405417	250-500	-	-
2012	LBSGE	Goat	-	-	4701	24	50-70	346019	250-500	-	-
2012	MTATA	Goat	-	-	9104	24	50-70	22411	250-500	-	-
2012	MT	Goat	-	-	5941	24	50-70	94186	250-500	-	-
2012	Or	Goat	-	-	3733	24	50-70	525208	250-500	-	-
2012	RSZCB	Goat	-	-	1134	24	50-70	143556	250-500	-	-
2012	SM	Goat	-	-	7626	24	50-70	143556	250-500	-	-
2012	TT	Goat	-	-	4107	24	50-70	454749	250-500	-	-
2012	THTFB	Goat	-	-	5093	24	50-70	427558	250-500	-	-

2013	CODA	Goat	-	-	548	21	50-70	473856	250-500	-	-
2013	GC	Goat	-	-	22	21	50-70	371278	250-500	-	-
2013	LBSGE	Goat	-	-	7847	21	50-70	337534	250-500	-	-
2013	MTATA	Goat	-	-	12297	21	50-70	30708	250-500	-	-
2013	MT	Goat	-	-	10238	21	50-70	100279	250-500	-	-
2013	Or	Goat	-	-	2861	21	50-70	409996	250-500	-	-
2013	RSZCB	Goat	-	-	960	21	50-70	152538	250-500	-	-
2013	SM	Goat	-	-	5096	21	50-70	63984	250-500	-	-
2013	TT	Goat	-	-	4334	21	50-70	530067	250-500	-	-
2013	THTFB	Goat	-	-	5885	21	50-70	436384	250-500	-	-
2014	CODA	Goat	-	-	863	27	50-70	436438	250-500	-	-
2014	GC	Goat	-	-	80	27	50-70	384869	250-500	-	-
2014	LBSGE	Goat	-	-	9442	27	50-70	329089	250-500	-	-
2014	MTATA	Goat	-	-	14535	27	50-70	32347	250-500	-	-
2014	MT	Goat	-	-	6981	27	50-70	95080	250-500	-	-
2014	Or	Goat	-	-	2182	27	50-70	513728	250-500	-	-
2014	RSZCB	Goat	-	-	1132	27	50-70	155245	250-500	-	-
2014	SM	Goat	-	-	3248	27	50-70	80991	250-500	-	-
2014	TT	Goat	-	-	4320	27	50-70	481750	250-500	-	-
2014	THTFB	Goat	-	-	5614	27	50-70	440952	250-500	-	-
2011	CODA	Camel	-	-	0	420	60-70	-	-	-	-
2011	GC	Camel	-	-	56	420	60-70	-	-	-	-
2011	LBSGE	Camel	-	-	1567	420	60-70	-	-	-	-
2011	MTATA	Camel	-	-	84	420	60-70	-	-	-	-
2011	MT	Camel	-	-	1	420	60-70	-	-	-	-
2011	Or	Camel	-	-	0	420	60-70	-	-	-	-
2011	RSZCB	Camel	-	-	9	420	60-70	-	-	-	-
2011	SM	Camel	-	-	88	420	60-70	-	-	-	-
2011	TT	Camel	-	-	0	420	60-70	-	-	-	-
2011	THTFB	Camel	-	-	25	420	60-70	-	-	-	-
2012	CODA	Camel	-	-	0	420	60-70	-	-	-	-
2012	GC	Camel	-	-	0	420	60-70	-	-	-	-
2012	LBSGE	Camel	-	-	3623	420	60-70	-	-	-	-
2012	MTATA	Camel	-	-	20	420	60-70	-	-	-	-
2012	MT	Camel	-	-	2	420	60-70	-	-	-	-
2012	Or	Camel	-	-	1	420	60-70	-	-	-	-
2012	RSZCB	Camel	-	-	18	420	60-70	-	-	-	-
2012	SM	Camel	-	-	50	420	60-70	-	-	-	-
2012	TT	Camel	-	-	0	420	60-70	-	-	-	-
2012	THTFB	Camel	-	-	11	420	60-70	-	-	-	-
2013	CODA	Camel	-	-	0	420	60-70	-	-	-	-

2013	GC	Camel	-	-	0	420	60-70	-	-	-	-
2013	LBSGE	Camel	-	-	4373	420	60-70	-	-	-	-
2013	MTATA	Camel	-	-	18	420	60-70	-	-	-	-
2013	MT	Camel	-	-	0	420	60-70	-	-	-	-
2013	Or	Camel	-	-	84	420	60-70	-	-	-	-
2013	RSZCB	Camel	-	-	8	420	60-70	-	-	-	-
2013	SM	Camel	-	-	29	420	60-70	-	-	-	-
2013	TT	Camel	-	-	0	420	60-70	-	-	-	-
2013	THTFB	Camel	-	-	2	420	60-70	-	-	-	-
2014	CODA	Camel	-	-	55	420	60-70	-	-	-	-
2014	GC	Camel	-	-	0	420	60-70	-	-	-	-
2014	LBSGE	Camel	-	-	3087	420	60-70	-	-	-	-
2014	MTATA	Camel	-	-	183	420	60-70	-	-	-	-
2014	MT	Camel	-	-	0	420	60-70	-	-	-	-
2014	Or	Camel	-	-	0	420	60-70	-	-	-	-
2014	RSZCB	Camel	-	-	11	420	60-70	-	-	-	-
2014	SM	Camel	-	-	18	420	60-70	-	-	-	-
2014	TT	Camel	-	-	0	420	60-70	-	-	-	-
2014	THTFB	Camel	-	-	5	420	60-70	-	-	-	-

Annexe VI

Supporting information 6: The age at onset of disease (a) from provincial hospital of Khenifra

Year	Sex	Age range	Age
2011	Women	15-19	16
2011	Women	20-24	22
2011	Women	25-29	29
2011	Women	30-34	30
2011	Women	30-34	31
2011	Women	40-44	41
2011	Women	40-44	42
2011	Women	40-44	42
2011	Women	40-44	44
2011	Women	45-49	45
2011	Women	50-54	50
2011	Women	50-54	53
2011	Women	55-59	55
2011	Women	55-59	56
2011	Women	70-74	71
2011	Men	15-19	17
2011	Men	20-24	20
2011	Men	20-24	21
2011	Men	30-34	31
2011	Men	30-34	32
2011	Men	30-34	33
2011	Men	45-49	47
2011	Men	55-59	56
2011	Men	65-69	65
2011	Men	65-69	66
2012	Women	20-24	20
2012	Women	25-29	26
2012	Women	25-29	26
2012	Women	25-29	28
2012	Women	30-34	30
2012	Women	30-34	31
2012	Women	30-34	31
2012	Women	40-44	41
2012	Women	40-44	42

2012	Women	40-44	43
2012	Women	40-44	48
2012	Men	20-24	20
2012	Men	25-29	26
2012	Men	40-44	40
2012	Men	40-44	40
2012	Men	40-44	43
2012	Men	50-54	53
2013	Women	25-29	27
2013	Women	30-34	30
2013	Women	30-34	32
2013	Women	35-39	35
2013	Women	40-44	41
2013	Women	40-44	43
2013	Women	50-54	53
2013	Women	50-54	54
2013	Women	60-64	60
2013	Women	60-64	60
2013	Women	60-64	64
2013	Men	30-34	30
2013	Men	30-34	31
2013	Men	30-34	33
2013	Men	30-34	33
2013	Men	35-39	38
2013	Men	35-39	39
2013	Men	40-44	43
2013	Men	50-54	50
2013	Men	50-54	50
2013	Men	50-54	50
2013	Men	55-59	59
2013	Men	60-64	60
2013	Men	60-64	60
2013	Men	60-64	63
2013	Men	70-74	70
2013	Men	70-74	70
2014	Women	30-34	30
2014	Women	30-34	32
2014	Women	35-39	35
2014	Women	35-39	36
2014	Women	35-39	38
2014	Women	35-39	39

2014	Women	40-44	40
2014	Women	40-44	40
2014	Women	40-44	40
2014	Women	40-44	41
2014	Women	40-44	43
2014	Women	45-49	45
2014	Women	45-49	46
2014	Women	45-49	48
2014	Women	50-54	50
2014	Women	50-54	50
2014	Women	50-54	52
2014	Women	55-59	56
2014	Women	60-64	60
2014	Women	60-64	60
2014	Women	60-64	61
2014	Men	20-24	23
2014	Men	35-39	39
2014	Men	40-44	40
2014	Men	40-44	40
2014	Men	40-44	41
2014	Men	45-49	45
2014	Men	50-54	51
2014	Men	50-54	52
2014	Men	55-59	58
2014	Men	60-64	62

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